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Vol. 202 SEPTEMBER, 1926 No. 3

SOLAR RADIATION AND WEATHER FORECASTING.*

BY

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AND

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In Charge of Solar Radiation Investigations, U. S. Weather Bureau.

INTRODUCTION.

For several years past many newspapers of this and other countries, and also some of our standard periodicals, have carried articles, often of a highly sensational character, on the subject of forecasting the weather for months, seasons, and even years. To add zest and attractiveness, they generally have forecast calamitous extremes of cold, drought and crop failure.

Popular interest in the weather, past, present, and especially of the future, is so great that such articles are assured of a cordial welcome, even though they are accorded a questioning acceptance by the more intelligent portion of the public. This interest and this doubt together explain why the Weather Bureau has received hundreds of appeals as to its opinion about these long-range forecasts and as to whether it believes the basis of them to be sound. And thus it also happens that we are very glad to have this opportunity of bringing before you our views on the possibility of scientific long-range weather forecasting.

The Smithsonian Institution has figured conspicuously in many of these sensational articles. Its opinions on the one hand and those of the Weather Bureau on the other, concerning impor-

* Presented by Doctor Kimball at a meeting held Thursday, April 15, 1926.

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tant scientific questions, have been made to appear as if in irreconcilable conflict, and the public has been led to believe that the Smithsonian Institution is making long-range weather forecasts based upon observations of the intensity of solar radiation made by its Astrophysical Observatory.

The following quotation from the last annual report of the Director of that Observatory [1] makes clear the position of the Smithsonian Institution on the question of forecasting:

"No public forecasts have been made or will be made under the auspices of the Smithsonian Institution. Our entire purpose in the matter is, and always has been, to make such experiments as might indicate what value, if any, would attach to the introduction of a new variable, namely, the variation of the sun, in weather forecasting. Our forecasts are made privately and only as tests of the experimental conclusions.

"Unfortunately, space writers in the public prints have not understood this and have attributed to the Smithsonian Institution forecasts of weather conditions far into the future. These, in reality, have been made by several private individuals entirely unconnected with the Institution. We take no responsibility for these prognostications, as we know as yet of no sound method by which they may be made."

The Weather Bureau has often warmly praised the great research which Doctor Abbot, in the face of almost insurmountable difficulties, has been conducting upon the problem of evaluating the solar constant of radiation. At every opportunity the bureau has given its assistance and coöperation, not because of any belief that the results of the observations give promise of being useful as a basis of either short or long-range forecasts, but on account of the great importance of Doctor Abbot's investigation in the domain of pure science. Obviously, we ought to know everything possible about the sun, and certainly a knowledge of the quantitative value of the total thermal energy we receive from it is of the highest importance. Doctor Abbot's determinations of this value vary to be sure, but they steadily increase in accuracy, and are unequalled in character and continuity by any other similar observations.

With this introductory statement we will proceed to examine his measurements of solar thermal energy and will try to arrive at a conclusion as to their weather-forecasting value.

THE PYRHELIOMETER.

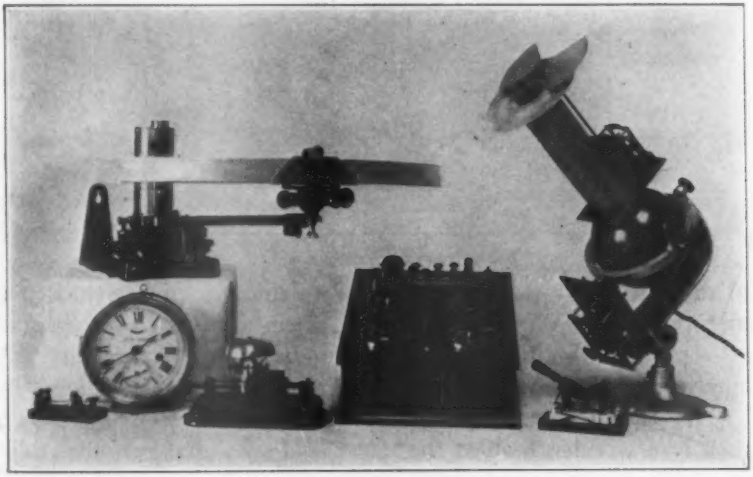
The pyrheliometer is the fundamental instrument in all measurements of intensity of the total solar thermal energy transmitted by the atmosphere to the place of observation. There are

FIG. 1.

Marvin pyrheliometer; cross-section of bulb.

several types of this instrument. The Marvin pyrheliometer (Fig. 1) is essentially an electrical resistance thermometer. Imbedded in a silver block about the size of a dollar is a non-inductively

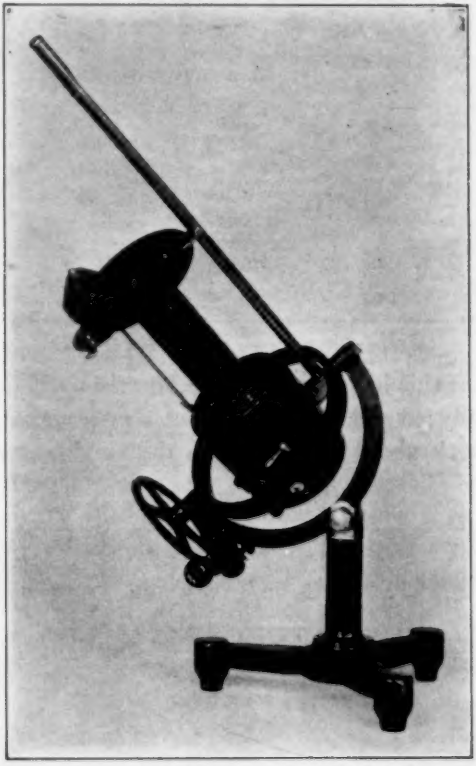
FIG. 2.



Marvin pyrheliometer and accessories.

wound insulated nickel wire in the form of a disc. The block has its front side blackened, and is placed in an insulating bulb (Fig. 2) at the end of a diaphragmed tube which is kept pointed towards the sun by a clock-driven equatorial mounting. A clock also causes a shutter during alternate minutes to shade and to expose to solar radiation the block and its contained wire. Care-

FIG. 3.



Smithsonian pyrheliometer.

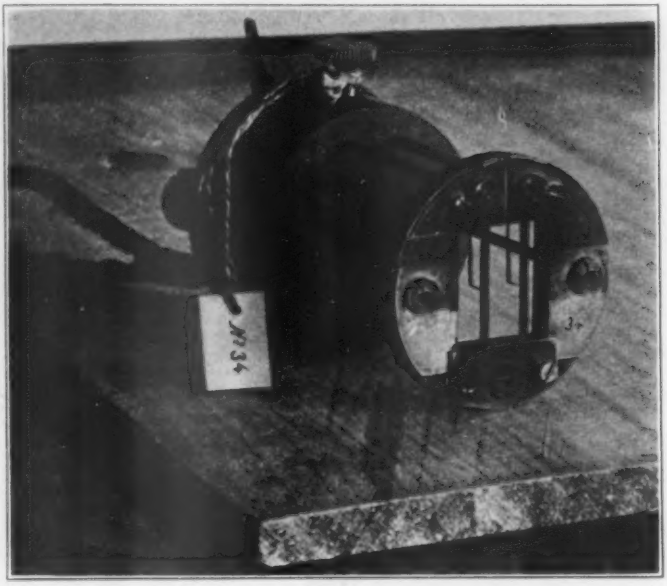
ful calibration of the wire permits its changes of resistance, as measured on a Wheatstone bridge, during periods of exposure and shading to be interpreted in terms of radiation intensity. A signal clock marks the time intervals for reading the bridge.

The Smithsonian pyrheliometer (Fig. 3) also has a silver block in a wooden bulb at the lower end of a diaphragmed tube, but the heatings and coolings are measured by a bent-tube mer-

curial thermometer, the bulb of which is inserted in the side of the silver block.

Of a different type is the Ångström electrical compensation pyrheliometer (Fig. 4). Two thin metal ribbons have attached to their backs, but insulated therefrom, copper-constantan thermo-electric couples. The faces of the strips are blackened. One strip

FIG. 4.

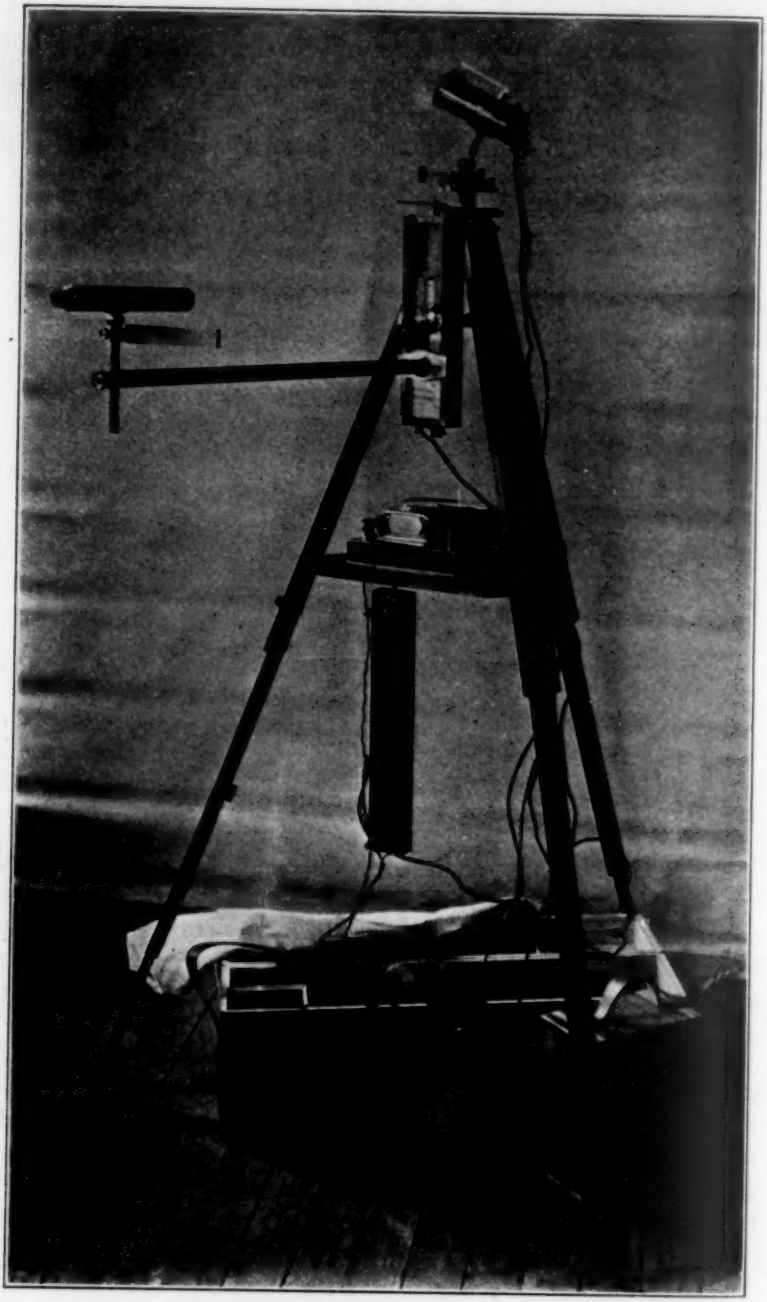


Ångström pyrheliometer; thermal elements.

is heated by exposure to solar rays (Fig. 5). An electric current is passed through the other of such strength that a galvanometer connected with the thermopile indicates temperature equilibrium between the two strips. Knowing the area and resistance of the strips, the amperage of this balancing current becomes a measure of the intensity of the solar thermal energy received.

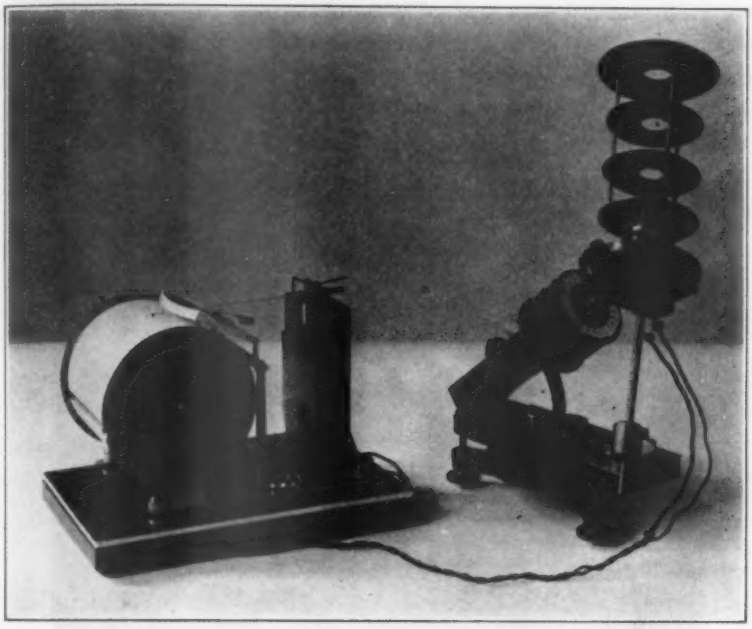
A recording pyrheliometer (Fig. 6), designed by Gorczyński, employs a series of thermocouples made by welding together the ends of thin strips of manganin and constantan and attaching the free ends to heavy pins set in a plate of copper. The strips are exposed to radiation throughout their length, but the junction that is attached to the heavy post is kept cool by conduction.

FIG. 5.



Ångström pyrheliometer and accessories.

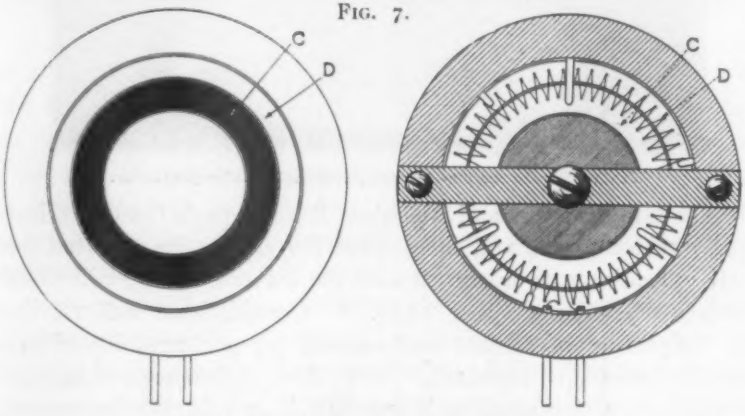
FIG. 6.



Gorczynski pyrheliometer and register.

The Weather Bureau thermo-electric pyrheliometer (Fig. 7) employs the same principle, except that one junction of each couple is attached to a ring having its front surface painted black.

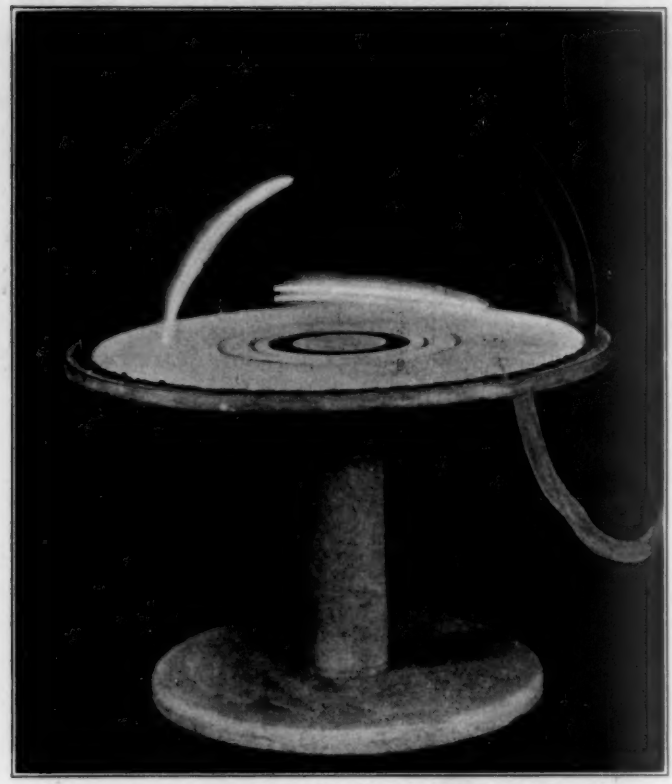
FIG. 7.



Weather Bureau thermo-electric pyrheliometer.

the other to a ring painted white. This instrument is either mounted at the lower end of a diaphragmed tube similar to the Marvin and the Gorczyński pyrheliometer tubes, or under a glass cover (Fig. 8), to record the total radiation received on a horizontal surface from the sun and sky.

FIG. 8.



Weather Bureau thermo-electric pyrheliometer under glass cover.

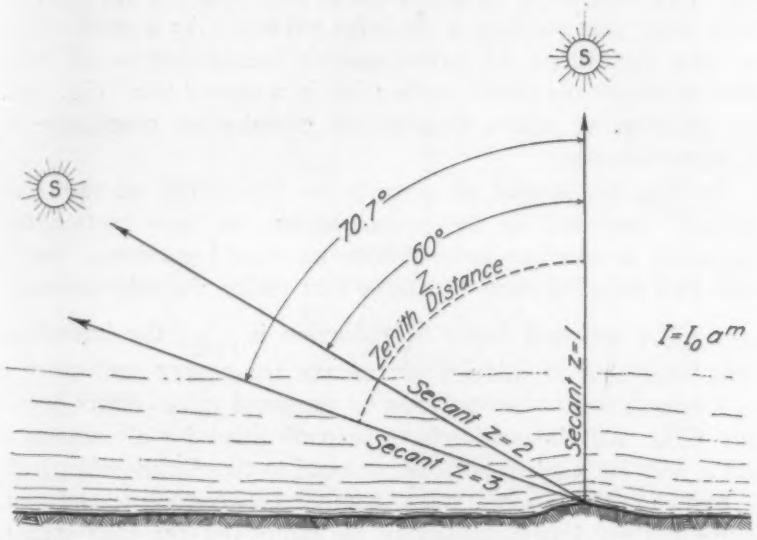
The Smithsonian and Weather Bureau pyrheliometers have been intercompared, and their reduction factors so adjusted that their indications are in accord with the scale of the "Smithsonian Revised Pyrheliometry of 1913."[2] Comparisons indicate that the Ångström instrument reads about 3.3 per cent. lower than the Smithsonian standard.[3] Of this difference, Ångström attributes 1.8 per cent. to structural defects in his instrument,

but considers the remaining 1.5 per cent. a subject for further investigation.

ATMOSPHERIC TRANSMISSION.

The atmosphere both absorbs and scatters the solar rays as they pass through it toward the earth's surface. The resulting depletion of the rays depends principally upon the altitude of the place of observation above sea-level, and upon the zenith distance of the sun. It is less on a mountain than in a valley, and less

FIG. 9.



Air mass, m = secant z.

at noon than in early morning or late afternoon. We speak of the length of the path of the sun's rays through the atmosphere as the air mass. With the sun in the zenith (Fig. 9), the air mass is considered unity; and for all positions of the sun air mass is approximately the secant of the sun's zenith distance. Thus, with the sun 60° from the zenith the air mass is 2.0, and with zenith distance 70.7° it is 3.0.

For monochromatic radiation the equation for atmospheric transmission is $I = I_0 a^m$, where I_0 is the intensity of the beam outside the atmosphere; a is the coefficient of atmospheric transmission for air mass 1.0, *i.e.*, with the sun in the zenith; m is the air

mass, and I the intensity at the place of observation. Passing to logarithms, the equation becomes $\log I = \log I_0 + m \log a$, which is the equation of a straight line. Therefore, if we plot as ordinates the logarithms of the intensity of monochromatic radiation measured with the sun at different zenith distances, with the corresponding air masses as abscissas, the logarithms should fall on a straight line (Fig. 10), of which the ordinate at zero air mass gives the logarithm of the intensity outside the atmosphere.

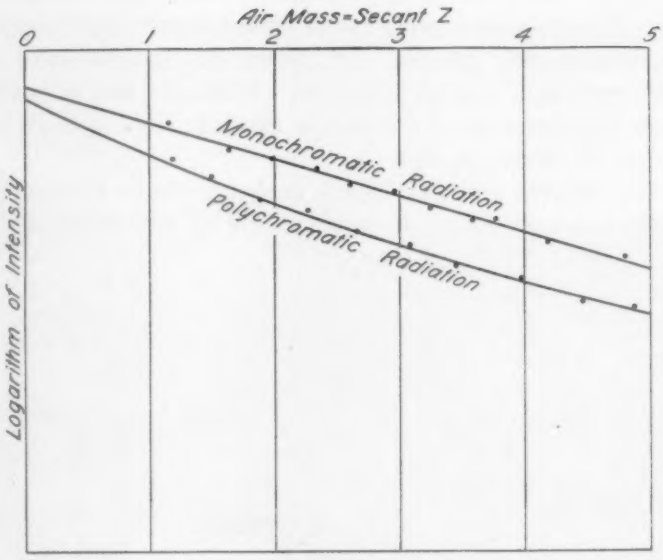
Solar radiation is polychromatic, however, and the rays of short wave-length, at the violet end of the spectrum, are depleted much more than the rays at the infra-red end. As a result, when we plot logarithms of pyrheliometric measurements of solar thermal energy, we find that they fall in a curved line (Fig. 10), the equation of which becomes so complex as practically to be indeterminable.

In Fig. 11, instead of plotting the logarithms of radiation intensity measured by the pyrheliometer, we have plotted the intensities themselves as ordinates on semi-logarithmic paper, after first reducing them to a scale that makes the solar constant 1.0. (The assumed factor of reduction is $\frac{1}{1.937}$, the intensities being expressed in calories per minute per square centimetre.) By extrapolation or interpolation of measured values where necessary (Fig. 10), intensities have been obtained for air masses 1 and 2, and for 3 when possible, reduced to the Smithsonian scale of pyrheliometry and to mean distance between earth and sun. A line is then drawn connecting the intensities for each station with the value at zero air mass. The numbers in the body of the diagram refer to the table at the lower left.

At some of the mountain stations observations for only a few days are available, while at low-level stations in some cases we have several years of observations. Both A.M. and P.M. measurements have been included in the mean data plotted in Fig. 11. At low-latitude stations, and at high latitudes in summer, the intensities average less in the afternoon than before noon.

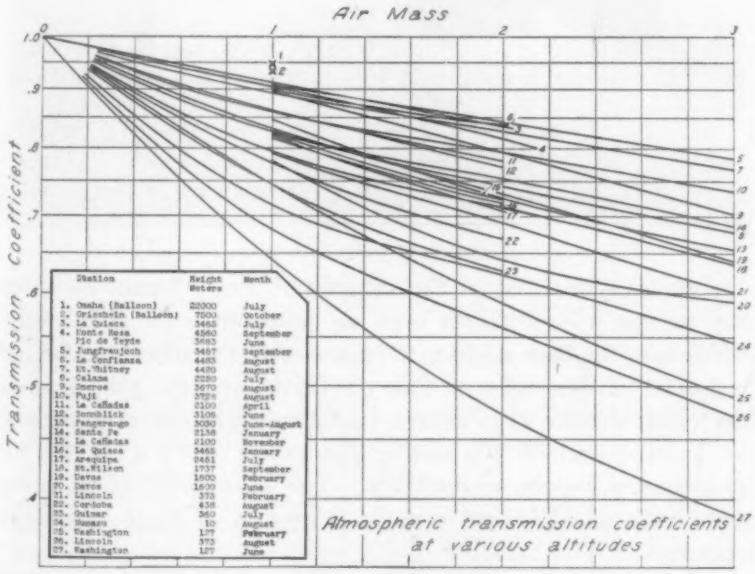
The ordinates of the numbered lines at air mass 1 give atmospheric transmission coefficients, a, for the designated stations. Thus, for 1, free balloon at 22,000 metres, $a = 0.95$; for 2, manned balloon, elevation 7500 metres, $a = 0.93$. Then we have a group

FIG. 10.



Logarithms of monochromatic and polychromatic radiation plotted against air mass.

FIG. 11.

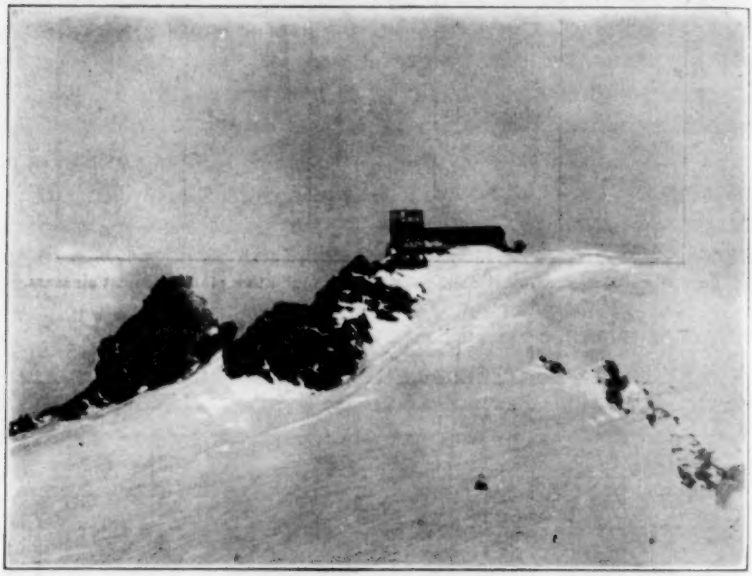

Air Mass
0
1
2
3
1.0
.9
.8
.7
.6
.5
.4
Transmission Coefficient
Atmospheric transmission coefficients at various altitudes
Station | Height Meters | Month
1. Omaha (Balloon) | 22000 | July
2. Griesheim (Balloon) | 7600 | October
3. La Quisca | 3468 | July
4. Monte Rosa | 4560 | September
Pic de Teyde | 3463 | June
5. Jungfraujoch | 3457 | September
6. La Confianza | 4483 | August
7. Mt. Whitney | 4420 | August
8. Calama | 2280 | July
9. Smeroe | 3670 | August
10. Fuji | 3728 | August
11. La Cañadas | 2100 | April
12. Zomblick | 3106 | June
13. Pangerango | 3030 | June-August
14. Santa Fe | 2138 | January
15. La Cañadas | 2100 | November
16. La Quisca | 3468 | January
17. Arequipa | 2461 | July
18. Mt. Wilson | 1737 | September
19. Davos | 1600 | February
20. Davos | 1600 | June
21. Lincoln | 373 | February
22. Cordoba | 436 | August
23. Quimar | 360 | July
24. Manaos | 10 | August
25. Washington | 177 | February
26. Lincoln | 373 | August
27. Washington | 127 | June

Atmospheric transmission coefficients at different altitudes.

of stations numbered 3, 4, 5, 6, and 7 with altitudes between 4560 and 3460 metres with values of a between 0.91 and 0.89, while Washington, altitude 127 metres, has for the value of a in February, 0.74, and in June, 0.64. Note also that at low-level stations the curvature of the lines is marked; while at high levels the lines are nearly straight.

With zenithal sun, atmospheric depletion due to scattering and absorption equals $1 - a$. It is interesting to note from synchro-

FIG. 12.



Observatory on Monte Rosa, Italy.

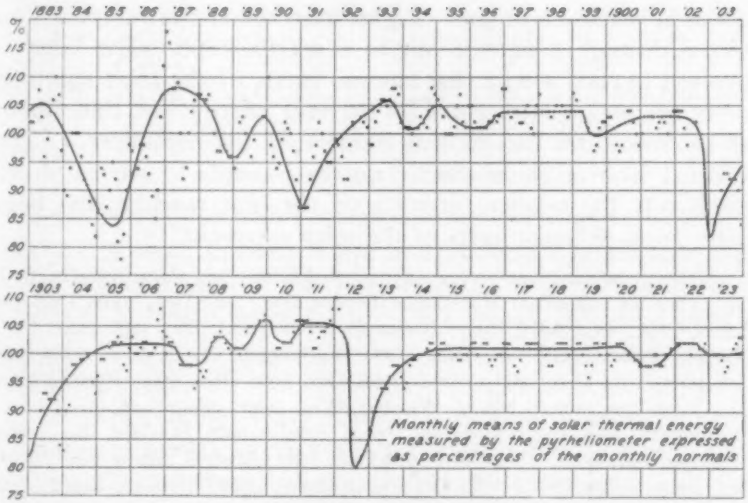
nous observations that at the summit of Fuji, Japan, elevation 3726 metres, $1 - a = 14$ per cent. as compared with 28 per cent. at Numazu, the base station, 10 metres above sea-level. Also, on the Island of Teneriffe, at Pico de Teyde, altitude 3683 metres, Alta Vista, altitude 3252 metres, La Cañada, altitude 2100 metres, and Guimar, altitude 360 metres, the values of $1 - a$ are 10, 11, 14, and 25 per cent., respectively. The superiority of measurements made at high-level stations in studies of solar variability is obvious.

Fig. 12 is a view of the observatory on Monte Rosa in the

FIG. 13.

Astrophysical Observatory, Smithsonian Institution, Mount Montezuma, Chile.

FIG. 14.



Monthly means of pyrheliometric measurements; percentages of monthly normals.

snow-clad Italian Alps at an altitude of 4560 metres. Fig. 13 is a view of the Astrophysical Observatory, Smithsonian Institution, on arid Mount Montezuma, Chile, at an altitude of 2900 metres.

In order to summarize pyrheliometric measurements, the monthly means of all available series extending over a considerable number of years have been expressed as percentages of the monthly normals. The results for each month for all the series have then been combined into a common mean, and these latter smoothed by the formula

$$\frac{a+2b+c}{4},$$

are plotted in Fig. 14. The outstanding features are the depressions in the values following the violent eruptions of Kratatoa, 1883, numerous volcanoes in 1890, Mont Pelé and volcanoes in Mexico and Central America in 1902, and Katmai in 1912. It is variations in atmospheric transmission that have caused the variations in this curve. It is unfortunate that all the long series of pyrheliometric measurements have been made at comparatively low-level stations.†

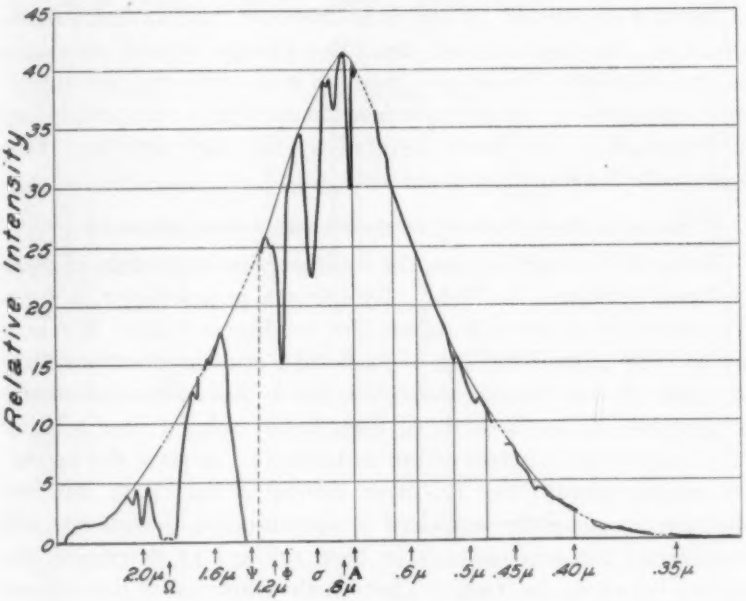
SPECTROBOLOMETRIC DETERMINATIONS OF THE SOLAR CONSTANT.

The bolometer is a highly sensitive heat-measuring instrument, which, like the Marvin pyrheliometer, is based upon the principle of the Wheatstone bridge. Light from the sun is reflected by a mirror through a narrow slit to a spectroscope. The latter is revolved in such a way that narrow bands of the solar spectrum are in succession intercepted by the very narrow and thin ribbon which constitutes the thermal element of the bolometer. Light reflected from a galvanometer mirror is made to record photographically the relative intensity of the heat reaching the bolometer from different parts of the solar spectrum.

† The pyrheliometric observations included in the data shown graphically in Fig. 14 are the following: Montpellier, France, Dec., 1882–Dec., 1900; Pavlovsk, Russia, Sept., 1892–April, 1913; Lausanne, Switzerland, Jan., 1896–Aug., 1904; Warsaw, Poland, Jan., 1901–Dec., 1918; Washington, D. C., June, 1905–Aug., 1911; Oct., 1914–Dec., 1923; Simla, India, Oct., 1906–Dec., 1915; Paris, France, Jan., 1907–Dec., 1923; Mount Weather, Va., Sept., 1907–Sept., 1914; Kew Observatory, Eng., Jan., 1908–Dec., 1922; Eskdalemuir, Scotland, Jan., 1909–Dec., 1922; Madison, Wis., July, 1910–Dec., 1923; Madrid, Spain, Sept., 1910–Dec., 1923; Santa Fé, N. M., Oct., 1912–March, 1922; Helwan, Egypt, Feb., 1914–Dec., 1923; Lincoln, Nebr., July, 1915–Dec., 1923.

We now pass to Fig. 15, a copy of a spectrobolometric energy curve obtained by the Smithsonian Institution at its observatory on Mount Wilson, Calif., in September, 1912.[4] By a system of rotating sectors in front of the slit of the spectroscope the amount of energy reaching the bolometer is controlled, so that the intensity of the ultra-violet end of the spectrum is on a much more open scale than here shown. The optical system used on Mount Wilson

FIG. 15.



Smithsonian spectrobolometric solar energy curve.

included a cœlostat with silvered mirrors and an ultra-violet glass prism. With this system it was not practicable to measure ultra-violet radiation below wave-length 0.34μ, and the measurement has little accuracy below 0.35μ.[5] On Mount Whitney, with an improved optical system, Abbot extended his measurements to 0.29μ.

Smithsonian observers obtain six or eight bolograms during a half-day period; the intensities (ordinates) at different wave-lengths are measured, and by straight-line extrapolation of their logarithms the relative intensity at zero air mass is closely

approximated. It is then possible to determine the relative areas under a computed bologram for zero air mass, and under the actual bolograms for different air masses. Pyrheliometer measurements are made in connection with the latter to permit of expressing all the areas in units of thermal energy. It is thus apparent that pyrheliometric readings are the fundamental measurements in determining the value of the radiation intensity at zero air mass, which is commonly called the solar constant.

The bolometer method, while theoretically exact, is open to two serious objections. First, it is laborious, and includes many corrections for depletion of the solar energy by the apparatus that are difficult to determine. Second, it assumes that the atmospheric transmission for all wave-lengths of light is constant during the period of a few hours covered by the observations. This assumption is almost never correct.

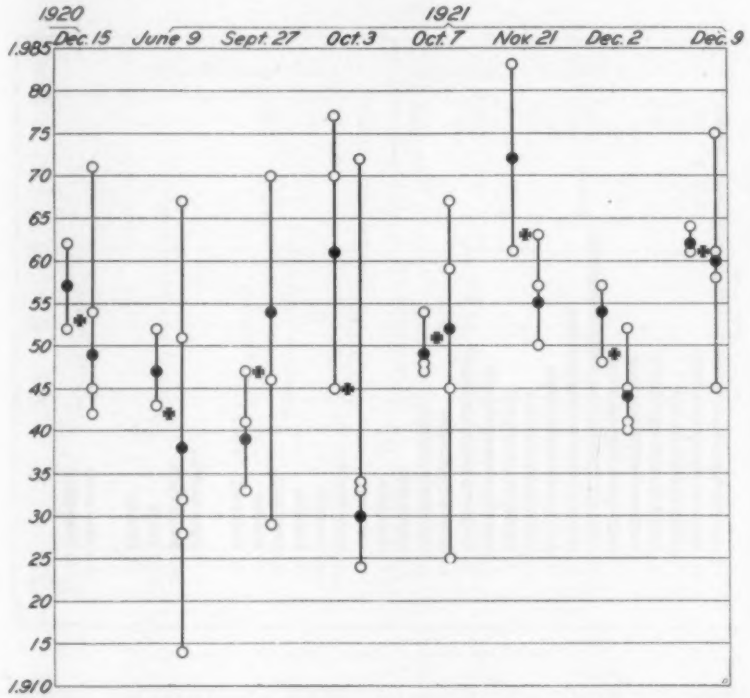
SHORT METHOD FOR DETERMINING THE SOLAR CONSTANT.

To avoid these difficulties, the Smithsonian Institution in 1920 developed a shorter method.[6] By using a pyranometer, a form of thermo-electric pyrheliometer, the brightness of the sky in a narrow ring around the sun is measured, and measurements are also made on water-vapor absorption bands in a spectrobolometric energy curve. The character of these bands bears a close relation to the water-vapor content of the atmosphere. Several sky brightness measurements may be made during a half day, but one bologram is generally sufficient. Simultaneous bolometer and pyranometer measurements have been utilized to determine the relation between the two. Then with empirically determined functions, as they are called, one bologram and three or four combined pyranometer and pyrheliometer readings allow the determination of a solar constant value for each pair of the latter readings. The functions must be determined independently for each station of observation.

We have selected individual pyranometer determinations on a few days from those published by Doctor Abbot [7] to illustrate the method of determining the mean solar constant value for the day. These are shown in Fig. 16. Under each date the circles in the left-hand row give values for Harqua Hala; in the right-hand row, for Montezuma. Open circles indicate individual

determinations; closed circles, mean station values, which are obtained by weighting the individual determinations. Crosses indicate the adopted mean value for the day, which is derived from the station means. Evidently the value for the day depends both upon the number of observing stations and the number of determinations made at each station. We can therefore under-

FIG. 16.



Individual and mean values of solar constant determinations.

stand why Doctor Abbot is anxious to establish one or two additional observatories.

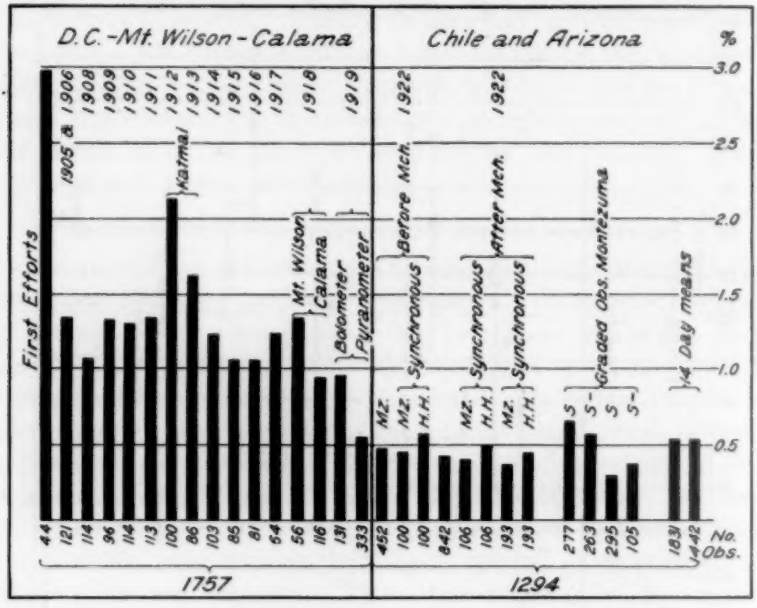
VARIABILITY OF SOLAR CONSTANT VALUES.

Determinations of the solar constant are no exception to the rule that all scientific measurements show fluctuations due to unavoidable errors. Other causes also may or may not produce fluctuations, but those due to error are never absent. Now, a rigid statistical analysis of the successive changes, usually those

from day-to-day, in more than 3000 solar constant values shows that as apparatus, methods and observing conditions have improved, these changes have *continually diminished*.

The probable variation of the early efforts at Washington and Mount Wilson (Fig. 17) was ± 3.0 per cent.; for later determinations about ± 1.3 per cent., which was increased to ± 2.2 per cent. in 1912 by dust from Katmai Volcano. At

FIG. 17.



Percentage variability of solar constant values.

Calama, Chile, in 1918–1919, still using the bolometric method, the variation was reduced to ± 0.9 per cent., and with the introduction of the new or short method of determination it was reduced to less than ± 0.5 per cent.‡ Fig. 18 shows clearly the

‡ The probable scatter due to all causes, including instrumental errors of observation and solar variability, has been determined by the well-known equation

$$e = \frac{.6745}{E_0}\sqrt{\frac{\Sigma v^2}{n-1}} = \frac{.6745}{E_0}\,\sigma$$

E_0 is the average value of the solar constant and σ is the standard deviation from the average.

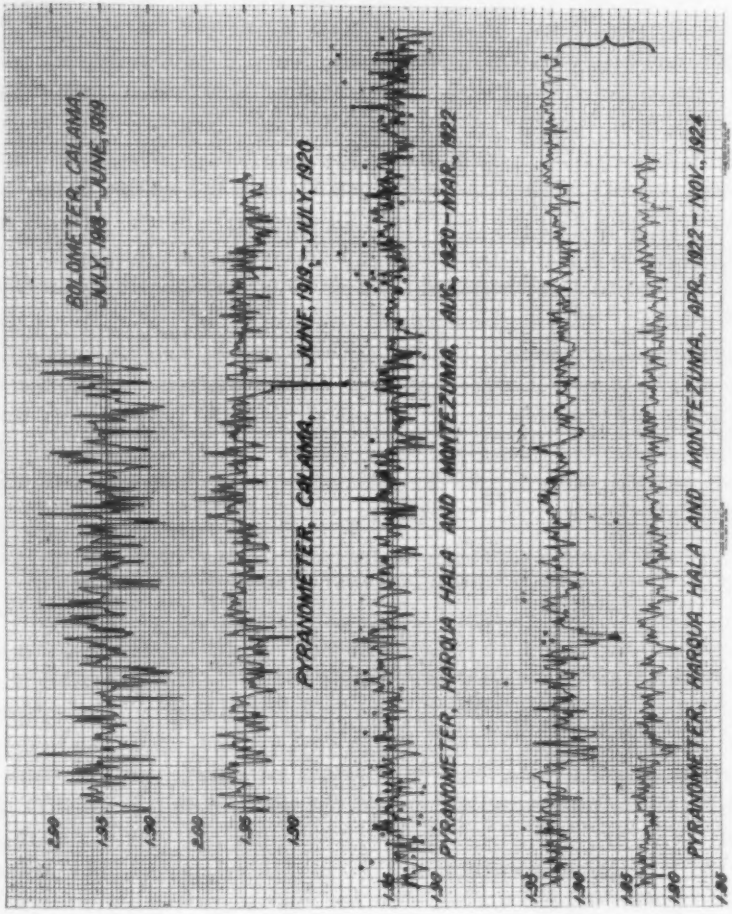

BOLOMETER, CALAMA,
JULY, 1918—JUNE, 1919
PYRANOMETER, CALAMA, JUNE, 1918—JULY, 1920
PYRANOMETER, HARQUA HALA AND MONTEZUMA, AUG., 1920—MAR., 1922
PYRANOMETER, HARQUA HALA AND MONTEZUMA, APR., 1922—NOV., 1924

FIG. 18.

Solar constant values, 1918-1924.

decrease in scatter after the adoption of the short method in 1919, and the still further decrease when values from two stations were obtained beginning with October, 1920. It also shows the decrease in the values between November, 1921, and September, 1922.

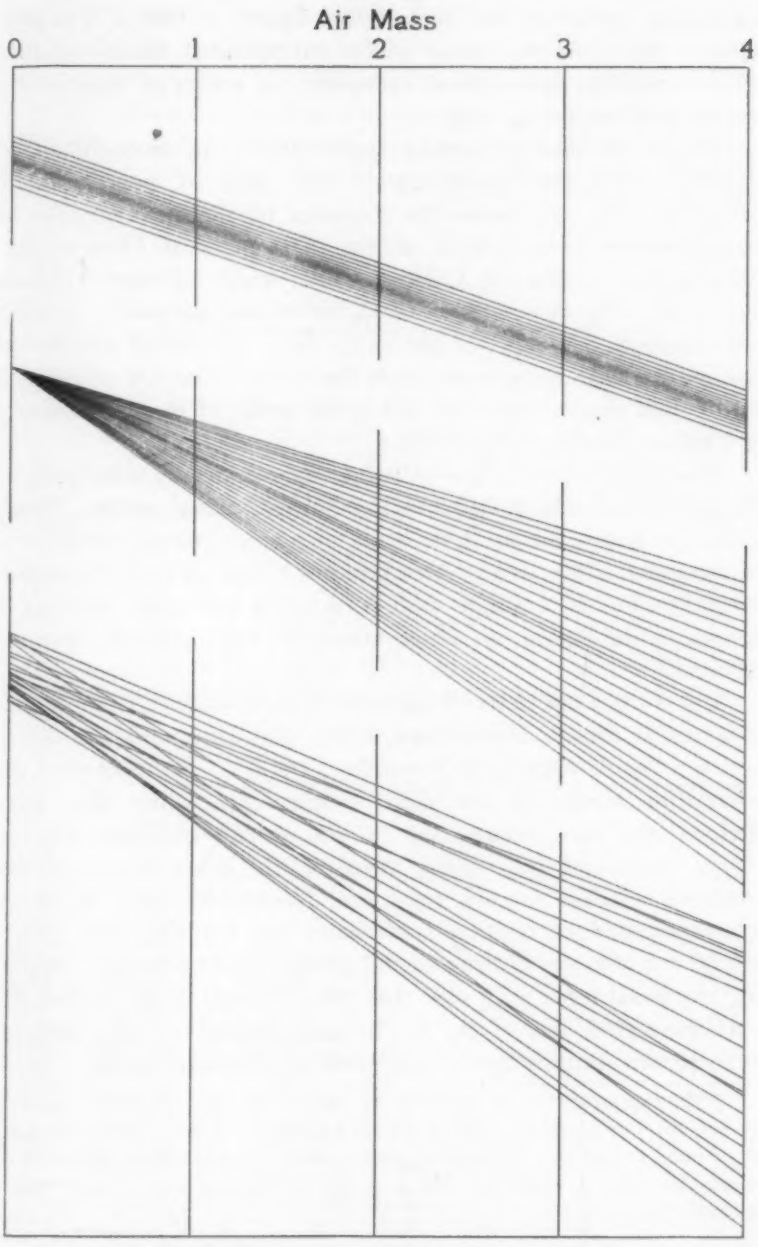
Let us make perfectly clear just what this ± 0.5 per cent. probable variability means. Suppose we derive the value of the solar constant on 1000 different days that are uniformly favorable for making observations, and compute how much each value differs from the average of all the values. Nearly all the departures are small in amount; a few scattering departures may reach ± 2 per cent.; but on the whole, half the values differ less than one-half of 1 per cent. from the average; and their frequency distribution approximates closely a Gaussian distribution.

Values of this character must be regarded as of a high order of accuracy; that is, the fluctuations are small and relatively unimportant. They follow a chance distribution. The foregoing are facts about which there seems to be no material difference of opinion. Moreover, we all recognize that the part of this total fluctuation not accounted for by observational errors may be due entirely to atmospheric variability, or to a combination of atmospheric *plus solar* variability.

INFLUENCE OF ERRORS OF DETERMINATION UPON SOLAR CONSTANT VARIABILITY.

We will now examine solar constant values to determine if possible how much of their variability is due to solar variations and how much to errors of determination. If the variation were all solar, and there were neither instrumental nor observational errors, nor changes in atmospheric transparency, then the lines of extrapolation to zero air mass would be parallel and accurately indicate the solar variability as in the upper part of Fig. 19. If, on the other hand, the solar radiation were a constant and there were neither instrumental nor observational errors, but atmospheric transmission varied, then the lines of extrapolation to zero air mass would meet in a point as shown in the central diagram of the figure. Finally, a combination of solar variability with variations in atmospheric transmission would give scatter in the extrapolations to zero atmosphere of the character shown in the lower part of Fig. 19. The observational errors, which we must

FIG. 19.



Scatter of monochromatic solar rays due to various causes.

add to either solar or atmospheric variability, would also cause scattering similar to that in the lower figure, so that it is impossible to tell from the scatter in the extrapolated values whether solar variability, atmospheric variability, or errors of observation are the predominating cause.

While the above remarks apply strictly to monochromatic radiation they are approximately true also of polychromatic radiation. Fig. 20 shows the character of the extrapolation of pyrheliometric observations at the Astrophysical Observatory, Smithsonian Institution, Calama, Chile, which of course include any or all of the three sources of variation just discussed. Broken lines connect readings for the same day. A central continuous line extrapolates to zero air mass the mean value for air masses 1 to 5, and similar lines extrapolate the mean of the values above and below this line, respectively.§

There are several ways of telling approximately what part of the scatter is due to instrumental and observational errors. Thus, Abbot estimates the probable error of pyrheliometric readings at Montezuma, Chile, to be ± 0.14 per cent.[8]; that of a solar constant determination at a single station, ± 0.335 per cent.; and of a determination based on observations at two stations, ± 0.237 per cent.[9]

Fig. 21 is a dot chart of 299 synchronous solar constant values obtained at Mount Montezuma, Chile, and Harqua Hala, Ariz., between April, 1922, and November, 1924.[10] To determine the correlation coefficient for these synchronous values they were divided into two groups, one of 106 values, obtained between April, 1922, and July, 1923, inclusive, the other of 193 values obtained between August, 1923, and November, 1924, inclusive. The computed correlation coefficients are for the first group, + 0.18 ± 0.063, and for the second group, + 0.17 ± 0.045. Applying the usual tests, it is seen that there is little evidence that the variations from day-to-day in the solar constant values obtained at these two stations can be attributed to a common cause.

§ The extrapolation is effected by means of the quadratic equation $y = y_0 + bm + cm^2$, where y and y_0 are the logarithms of the radiation intensity at air mass m and zero, respectively, and b and c are atmospheric transmission terms that may be obtained from a series of observations by least square methods.

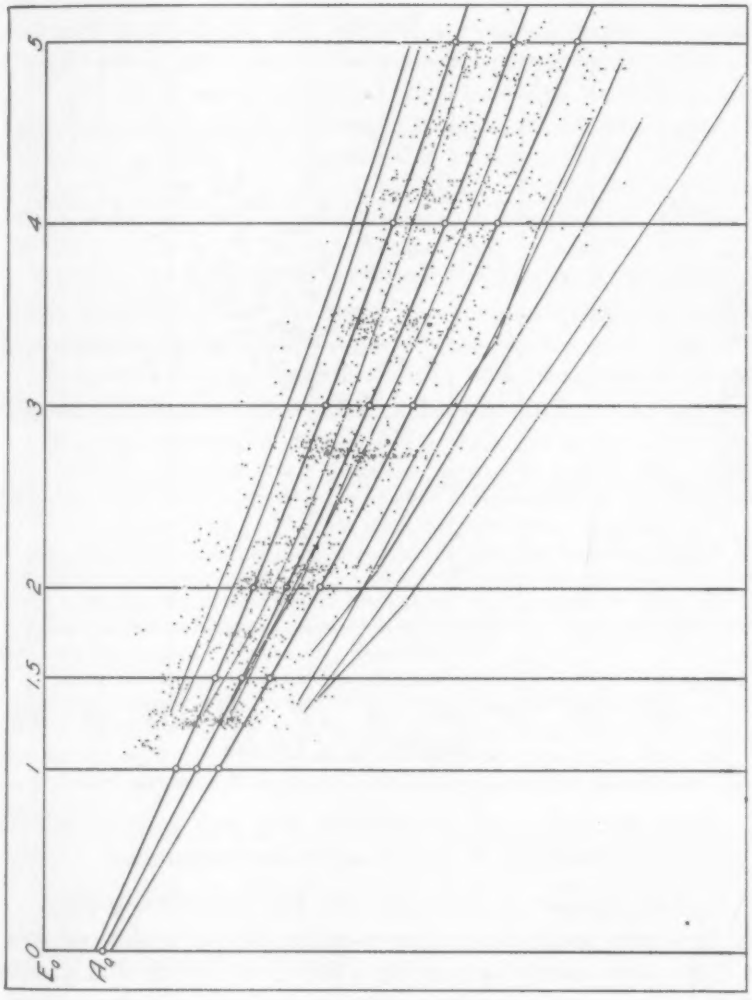
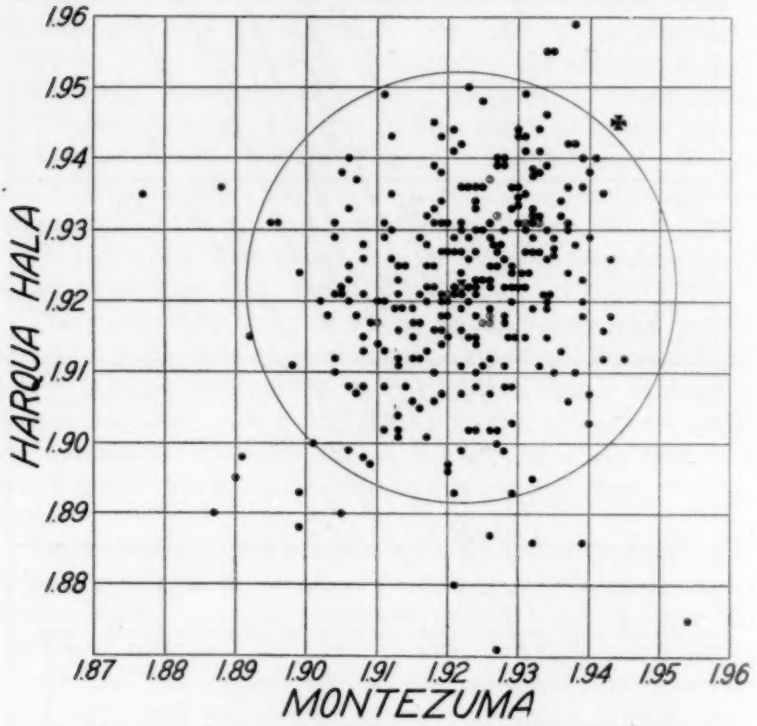


FIG. 20.—Scatter of Calama pyrheliometer observations.

Furthermore, Doctor Abbot [11] finds that the average difference between Chile and Arizona is about one-half of 1 per cent. This means, he says, "That on many days our estimate of the condition of solar radiation may be as much as 1 per cent. wrong."

FIG. 21.



Synchronous solar constant determinations at Harqua Hala and Montezuma.

From the foregoing, we conclude that such solar variability as exists is submerged in the errors of determination.

SOLAR CONSTANT VARIABILITY AND WEATHER FORECASTING.

Now, the great outstanding question on the subject of solar radiation and weather forecasting which awaits a scientific answer is this: Can an apparent fluctuation in total solar thermal energy, which by the most accurate measurement amounts to less than half of 1 per cent., constitute a scientific basis for weather forecasts for either short or long periods in advance?

Mr. H. H. Clayton, an experienced forecaster,[12] has taken extreme views on the affirmative side of this question. He has stated his position thus: "(1) If there were no variation in solar radiation the atmospheric motions would establish a stable system with exchanges of air between equator and pole and between ocean and land in which the only variations would be daily and annual changes set in operation by the relative motions of the earth and sun; (2) the existing abnormal changes which we call weather have their origin chiefly, if not entirely, in the variation of solar radiation." Abbot[13] interprets this to mean "that all we call weather—symbol for all that is variable, in distinction to climate, which is the steady, average condition of things—is really due to the sun's variation." These views are quite in contrast with those of Bjerknes on the polar front[14] and of Shaw on the atmospheric steam engine,[15] which are based on purely thermodynamic and hydrodynamic principles.

We wish also to quote here from the press release by the Smithsonian Institution dated December 9, 1925:

"Since there is nothing so convincing of discovery as ability to forecast, Mr. Clayton" (formerly Chief Forecaster of the Argentine Meteorological Service) "undertook forecasts of maximum temperatures for the great city of New York, based on Smithsonian solar constant values received daily from its two stations in Chile and California, somewhat similar to those which he had inaugurated for Buenos Aires. Mr. Clayton received advices about twenty-four hours after the solar observations were made, he prepared his forecasts for three, four, five, and twenty-seven days in advance, and transmitted them the same afternoon to the Smithsonian Institution.

"After over a year of these forecasts had accumulated, they were compared at the Smithsonian Institution with the actual maximum temperatures at New York as published by the Weather Bureau. The twenty-seven-day forecasts showed nothing, but all the others clearly indicated pre-vision. These are, of course, only provisional results. For several reasons the correlations could not be high. . . .

"What stands out clearly is this: (1) Real pre-vision of weather conditions is shown. It is based on a new element, the solar variation, which, except in Argentine, has hitherto never been taken into account among weather services of any of the governments of the world. (2) The accuracy even now attained is sufficient to make Mr. Clayton's forecasts of the weather of next week, or next month, decidedly better in the long run than a mere guess."

It is unfortunately true that publication of statements like the above and of press reports which are inspired, and even justified, by such statements, have led to serious misunderstanding on the part of the general public. The layman is allowed to infer

that these imperfectly successful forecasts express relationships between the temperature at New York City and the derived values of the solar constant, three, four, and five or more days before. This inference, however, is not fully warranted, in view of Mr. Clayton's printed statement as follows:[16]

"At first the three- to five-day forecasts were based largely on the relations shown in figures 2 and 3, later these were supplemented by direct observations of the sun and the relations shown in figures 38 and 39 were also used in forecasting. These were supplemented by telegrams of the maximum temperature observed at Seattle, Williston, and Chicago, in order to ascertain to what extent the temperatures at those stations were responding to solar changes."

Mr. Clayton has personally told members of the Weather Bureau that his forecasts for three to twenty-seven days in advance are made not alone from the provisional values of the solar constant, but that he is aided by all his past experience in forecasting from weather maps and also by a knowledge of the general weather as it prevails over the United States at the time the forecast is made.

Recently, one of the professional forecasters of the Weather Bureau made forecasts of the maximum temperature at New York City three days ahead for the period covered by Clayton's forecasts, namely, December 1, 1923, to November 30, 1924. In this test only the most superficial examination of the weather maps was made. Only six or seven minutes were allowed for determining and setting down the probable temperatures for an entire month, or an average of about five forecasts a minute. Later the departure from normal of each predicted temperature was determined and the forecasts were then classified according to the method employed by Mr. Clayton.

The mean results of the forecasts are tabulated below and give the mean departure of maximum temperature for days when the forecast was 5° F. or more above normal, or high, 5° F. or more below normal, or low, and between these extremes, or normal.

Forecast Three Days Ahead.	High.	Normal.	Low.	High-Low.
Clayton	+ 1.6°	− 0.6°	− 1.0°	+ 2.6°
Weather Bureau	+ 2.8°	− 0.6°	− 4.0°	+ 6.8°

The above verifications superficially show that the Weather Bureau forecasts were rather successful, but they were unsatisfac-

tory to the forecaster because of the fact that only forty-two of the sixty-seven forecasts of temperature 5° or more above normal showed a positive departure, and only fifty-four of the eighty forecasts of 5° or more below normal showed a negative departure. The large average departures shown are due to the very great departures of the proper sign in a number of instances. Thus the distinct failures are covered up in the mean results. The British meteorologist, F. J. W. Whipple,[17] comments on Clayton's forecasts as follows: "There is no attempt to show that the results are not attributable to chance and, indeed, the general run of the (Clayton) graphs is in accord with the hypothesis that they are."

It is very plain, therefore, to the experienced meteorologist, that the small pre-vision shown by Mr. Clayton's forecasts do not prove anything at all about the direct influence of solar fluctuations on New York City temperatures. Nor can they until Mr. Clayton proves that one can forecast with the help of the solar constant alone, independent of any knowledge of prevailing weather, or until he demonstrates that equally conscientious forecasts, without the aid of the solar constant values, show less pre-vision than with their aid. Obviously, such a test is a very difficult one to make, and Mr. Clayton has said personally to one of the authors that he knows of no way to determine what part of his pre-vision depends upon knowledge of the weather map and what part can properly be attributed to his knowledge of the sun.

VARIABILITY OF SOLAR THERMAL ENERGY MEASUREMENTS AT THE EARTH'S SURFACE.

Let us now read the story of the variability of solar thermal energy as measured on a horizontal plane at the surface of the earth by the pyrheliometer. It is data on this aspect of pyrheliometry in which meteorologists are most interested. Indeed, Sir Napier Shaw [18] calls it "the fundamental basis of the science of meteorology." The earth's surface is a very active absorber of solar energy. It largely controls, through radiation and conduction, the temperature of the air above it. Consequently, the greatest changes in atmospheric temperature are in general found within a few hundred metres of the ground.

There are two recognized periodic variations in the receipt of solar energy. One is the diurnal, the other the annual. The annual results from the combination of two causes, namely,

changes in the earth's distance from the sun and changes in the sun's declination. A third possible periodic change may be due to variation in intensity of solar radiation with the eleven-year sun-spot period.

The diurnal change is from 0 during the night to a maximum of varying amount at mid-day. Fig. 22, which is a reproduction of records from a Weather Bureau thermo-electric pyrheliometer, gives illustrations of the diurnal variation. The upper curve is for the intensity of solar radiation at normal incidence; the middle curve, the intensity of the total radiation from the sun and sky received on a horizontal surface; the lower curve, the intensity of the diffuse radiation received from the sky alone, obtained by placing a shade between the pyrheliometer and the sun.

Considering now the annual changes, the curves of Fig. 23 show the annual march of the daily totals of energy expressed in kilowatt-hours per square dekametre of horizontal surface. A square dekametre is equal to 1076 square feet, or to an area about 20 by 54 feet, which is the area covered by an ordinary house. A kilowatt-hour of energy is sufficient to maintain twenty-five 40-watt electric lamps for one hour. The upper curve shows the daily totals at the outer limit of the atmosphere for the latitude of Washington as derived from Angot's "Researches on the Distribution of Heat at the Surface of the Globe," [19] by assigning to the solar constant Abbot's mean value, 1.937 gr. cal. per min. per cm.^{2}, or its equivalent, 135 kilowatts per square dekametre. The middle curve gives the daily total at the surface of the ground at Washington with a cloudless sky, and the lower curve the total with average sky conditions. These two latter curves are based on ten-year weekly mean values for Washington, as measured by recording pyrheliometers, and smoothed by the formula

$$\frac{a+2b+c}{4}.$$

The greatest factor controlling the form of these curves is obviously solar declination; but the annually changing distance between earth and sun enters as a minor factor. The maximum distance occurs about July 3rd, and is sufficient to decrease the solar thermal energy 3.5 per cent. below what it would have been had the earth been at mean solar distance. The minimum distance occurs about January 3rd, and is sufficient to increase the solar thermal energy 3.5 per cent. This is a periodic change

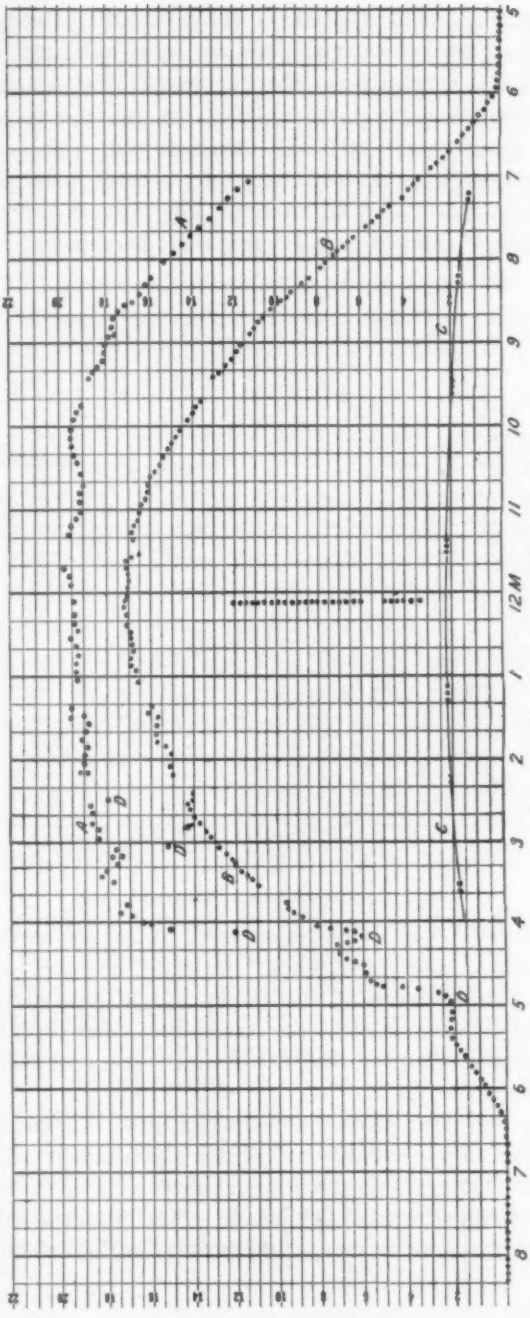
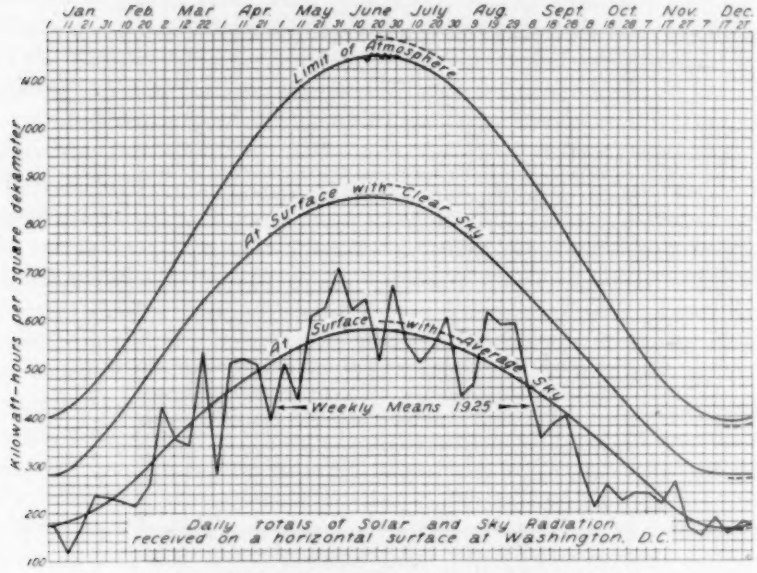


FIG. 22.

Record from Weather Bureau thermo-electric pyrheliometer.

of 7 per cent., having an interval of six months between extremes. By means of broken curved lines we have indicated what would have been the intensity on the curves of Fig. 23 at maximum and minimum had the earth remained at mean solar distance, as it is on about April 3rd and October 3rd. This 7 per cent. change exceeds in magnitude any long-period variation found by Abbot in his solar constant values. The nearest approach to it is the decrease in intensity of 2.6 per cent. between monthly means

FIG. 23.


Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec.
Limit of Atmosphere
At Surface with Clear Sky
At Surface with Average Sky
Weekly Means 1925
Kilowatt-hours per square dekameter
Daily totals of Solar and Sky Radiation received on a horizontal surface at Washington, D.C.

Daily totals of radiation at Washington, D.C.

for November, 1921, and September, 1922, inclusive; a period of ten months. Our researches [20] indicate, however, that at least a part of this decrease is due to an annual periodicity that has been found to exist in the solar constant values published by the Smithsonian Institution, and which must be attributed to atmospheric influences.

Superposed upon all the periodic changes are non-periodic fluctuations due to sky conditions. Such fluctuations are shown by the irregular line along the lower curve of Fig. 23. This line gives the weekly means for 1925. And superposed upon the irregularities in weekly means, there may be the day-to-day varia-

tions in the solar constant, as determined by the Smithsonian Institution. On the upper curve is indicated the magnitude of the changes measured by Doctor Abbot between June 12 and July 2, 1924. During this twenty-one-day period a satisfactory value of the solar constant was obtained every day. Equally satisfactory measurements were made throughout July, and show somewhat less variation than the June values. It is hard to see how these variations, the maximum of which is less than 1 per cent. from the mean for the month, when superposed upon the variations already mentioned, could have an appreciable effect on the amount of radiation received at the surface of the earth.

THERMODYNAMIC EFFECTS OF VARIABLE SOLAR THERMAL RECEIPT.

We have already mentioned the importance of solar radiation data to the science of meteorology. It will be well to expand this thought further. The thermodynamic effects of the periodic solar thermal energy variations are well known. In general, on each clear day, after sunrise the temperature increases, rapidly at first, and then more slowly, until a maximum is reached from two to four hours after noon, when the air begins to cool. If the surface heating is excessive, and the air sufficiently moist, thunder-storms, often of great violence, may result. A cloudy sky, which decreases the intensity of the incoming heat, diminishes the rise of temperature during the day. In response to the annual period due to inclination of the earth's axis, the daily means of temperature reach a maximum, not at the summer solstice, but at least a month later, and a minimum about a month after the winter solstice.

The pressure distribution over land and sea gradually responds to changes in temperature distribution. Atmospheric motions result, which vary with the seasons, becoming most violent when the latitudinal temperature differences are at a maximum. The motions would be comparatively steady were the earth's surface frictionless and homogeneous in character throughout. Differences between the temperature over land and sea, uneven surfaces of land masses, and especially the rotation of the earth, cause turbulent motions out of which result storms, cold waves, hot winds, and the whole train of variations in the meteorological elements which we call weather.

We can forecast the weather only for the period during which the course of these turbulent motions can be foretold. The length of this period depends upon the accuracy and detail of our observation of the factors producing the motions, and upon our skill in assigning to each its proper weight.

We have tried to show the basis for our belief that the weight assignable to solar variability as a factor in the making of the weather is almost vanishingly small. But shall we say, then, that meteorologists in general and weather forecasters in particular are not to benefit from more accurate determinations of the value of the solar constant? By no means. It is the solar energy absorbed by the earth and its atmosphere that keeps the atmospheric heat engine going. It is the changes in absorption that control the behavior of the engine in detail, with respect to both time and place.

And let us make perfectly clear that although we believe these ever-changing conditions are far more important to the business of forecasting than can ever be the minute fluctuations in total solar output, the very existence of which is still in doubt, we recognize that a fundamental need is for accurate knowledge of the value of the solar constant. Without it, our pyrheliometric measurements can give us but an approximate idea of atmospheric absorption.

The work of Doctor Abbot and his colleagues not only has given us the value of the solar constant, but also has added greatly to our knowledge of the laws of atmospheric absorption. The work already accomplished will be an enduring monument to their devotion to science. Abbot [21] and Pettit [22] find variations in their measurements of the ultra-violet that far exceed those in Abbot's determinations of the solar constant. Dorno [23] and others suggest that variations in the ultra-violet may influence the permeability of the atmosphere, especially in its higher layers. The fundamental importance to science of Doctor Abbot's investigations becomes, therefore, increasingly clear. Unquestionably we must extend our research into the region of the ultra-violet. Quoting from Doctor Abbot, " Perhaps we may find later on that observations with ultra-violet rays will prove a highly useful factor . . . ".[24] May we not safely predict that in the broadened

field of endeavor upon which Doctor Abbot and his colleagues are entering, yet more important contributions to our knowledge of the sun and its effects upon the earth's atmosphere may be forthcoming?

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Improved Grating for Vacuum Spectrographs. R. W. WOOD and THEODORE LYMAN. (*Phil. Mag.*, July, 1926.)—In the use of gratings within the vacuum of spectrographs used in the study of short wave-lengths a disadvantage has been the tarnishing of the metal by the vapors coming from the discharge tube. Professor Lyman remedied this partially by pumping them out before they had full opportunity to attack the metal of the grating. It was thought that glass gratings would be superior to those of metal not only because they could be readily cleaned, but also since glass should have a higher reflecting power for very short wave-lengths. Metals reflect less and less of the incident radiation as its wave-length is shortened, while transparent substances reflect more and more. The coefficients of these two types of substances are about the same for wave-lengths of 2000 Å.U. and the radiation to be examined by the vacuum spectrograph is still shorter in wave-length than this.

One glass grating was prepared but destroyed by fire. The dividing engines at Johns Hopkins University have been so busy that not until the spring of 1926 were experiments on glass gratings resumed. Now three such gratings have been ruled, a light pressure on the diamond point being used to prolong its life. Scarcely any spectra can be seen with one of these concave gratings freshly ruled. The grating is then etched with dilute hydrofluoric acid to put the surface in the form to give bright spectra. One of these glass gratings with a meter radius, ruled surface 5×8 cm. with 15,000 lines to the inch, has been tested at Harvard. Comparison was made between the performances of this and of a speculum metal grating that manifested but little decrease of reflecting power in the extreme ultra-violet after eighteen months in the vacuum spectrograph. For wave-lengths longer than 1400 Å.U. the metal grating had the advantage. The glass grating, however, has a distinct superiority from 500 Å.U. down, especially between 200 and 300 Å.U. A photograph is reproduced, showing the spectra of a spark between copper terminals obtained from the two different gratings with the same length of exposure. The superiority of the glass grating in the shorter wave-lengths is very striking. G. F. S.

POWER POSSIBILITIES OF COAL BY-PRODUCTS.*

BY

WILLIAM H. BLAUVELT, E.M., M.S.

I HAVE been asked to speak on "The Power Possibilities of Coal By-products," but I was told by the Chairman that I might depart in some slight degree from the exact terminology of my subject—but I hope to hold to it as closely as circumstances will permit, because I understand other speeches are to follow in consecutive order.

Commercially speaking, there are two fuels available for industrial and domestic use, namely, coal and petroleum. Except for the energy developed by falling water, coal and petroleum are our only sources of mechanical power. The production of power economically and in large quantities has made our mechanical age what it is. If our sources of power should fail we should return to the pastoral age. Very many of our comforts and much that makes what we call our present civilization would disappear, and in most countries the land would by no means furnish sufficient food to maintain anything like the present population. These statements may seem quite academic when we remember the enormous deposits of coal still untouched in various parts of the world and we may have optimistic impressions of the future of the petroleum industry. There is no doubt that our supplies of coal will be available for many years to come and neither we nor our children's children will have any cause for alarm as to immediate shortages. But our best and most cheaply mined coals are already becoming scarcer.

Regarding the petroleum supplies, there are widely differing opinions. Some authorities state that the supply of the United States will be conserved for many years to come "by some means which will be discovered to secure much larger percentages of the oil in the ground."

Others go so far in the opposite direction as to estimate that the present rate of production from all known sources of petro-

* Presented at a joint meeting of The Franklin Institute, the Engineers' Club, the American Society of Mechanical Engineers, Philadelphia Section, and the American Chemical Society, Philadelphia Chapter, held Friday, April 23, 1926, in celebration of Oil and Gas Power Week.

leum in the United States can be sustained for only eight years. Most of us have little conception of the enormous rate at which our petroleum resources are being withdrawn. If all the oil produced in the State of Pennsylvania since Colonel Drake's discovery up to the present time were collected in one great tank, it would supply the requirements of the United States for only thirteen months, and if all the oil produced east of the Mississippi River from the first discoveries up to the present time were similarly collected, it would equal our present consumption for thirty-five months.

(It doesn't seem that the eight-year limit is perhaps as wild as some of our petroleum people would ask us to believe.)

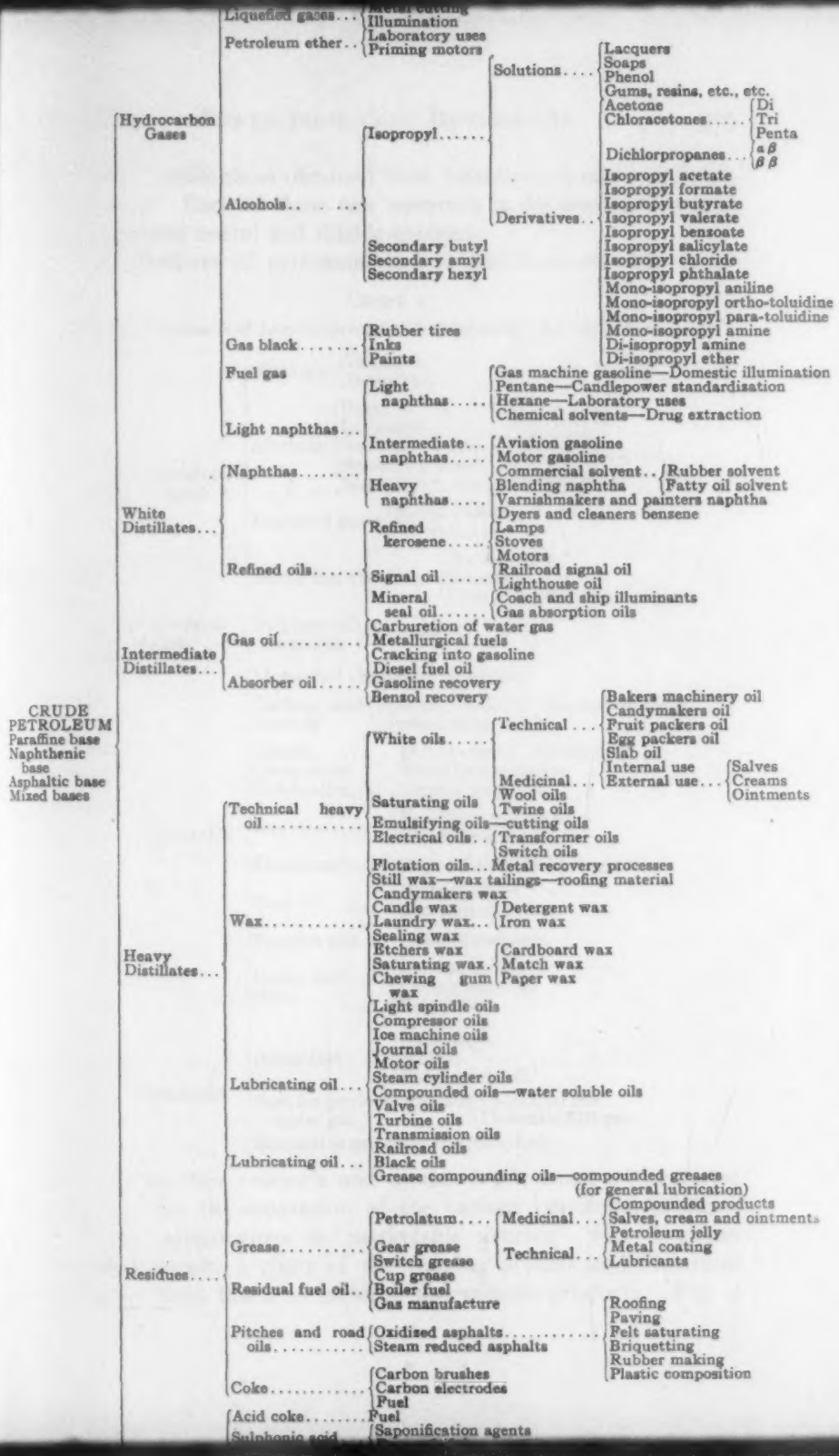
Although opinions of experts differ, there is no doubt that our available supplies of petroleum will shortly be on the wane and as it grows more scarce, it must be reserved more and more for special uses where its particular qualities give the highest values. As this paragraph is being written, it is reported that one of the great oil companies is preparing to burn coal instead of oil in some of its refineries because of the increased value of fuel oil. The increasing number of uses for petroleum and the rising prices resulting therefrom call imperatively for a substitute. Shale oil has been suggested, but unfortunately nature selected locations for oil-shale deposits quite remote in almost every case from our industrial centres. Moreover, in the production of shale oil, the solid residue is practically worthless, so that the residue disposed of is equal in bulk to the original shale as it comes from the mine or quarry. Coal is the other possible source of oils as of a composition similar to that of petroleum. Can such oil be economically obtained in coal? If so, by what process?

(That is a question that I shall leave to other speakers to answer more in detail.)

Whether this search is successful or not, true economy demands that wherever coal is employed in the arts, it must be used in the most economical manner.

We should have to go back very far toward the date of the original discovery of petroleum to find it used in its crude state as is so much of our coal. This situation is not due to the lack of salable products that may be obtained from the processing of raw coal as compared with petroleum.

The principal products obtained from petroleum are listed


CRUDE PETROLEUM
Paraffine base
Naphthenic base
Asphaltic base
Mixed bases
Hydrocarbon Gases
Liquefied gases
Illumination
Laboratory uses
Petroleum ether
Priming motors
Isopropyl
Solutions
Lacquers
Soaps
Phenol
Gums, resins, etc., etc.
Acetone
Chloracetones
Di
Tri
Penta
Dichlorpropanes
α β
β β
Alcohols
Derivatives
Isopropyl acetate
Isopropyl formate
Isopropyl butyrate
Isopropyl valerate
Isopropyl benzoate
Isopropyl salicylate
Isopropyl chloride
Isopropyl phthalate
Mono-isopropyl aniline
Mono-isopropyl ortho-toluidine
Mono-isopropyl para-toluidine
Mono-isopropyl amine
Di-isopropyl amine
Di-isopropyl ether
Secondary butyl
Secondary amyl
Secondary hexyl
Gas black
Rubber tires
Inks
Paints
Fuel gas
Gas machine gasoline—Domestic illumination
Light naphthas
Pentane—Candlepower standardization
Hexane—Laboratory uses
Chemical solvents—Drug extraction
Light naphthas
White Distillates
Naphthas
Intermediate naphthas
Aviation gasoline
Motor gasoline
Commercial solvent
Rubber solvent
Heavy naphthas
Blending naphtha
Fatty oil solvent
Varnishmakers and painters naphtha
Dyers and cleaners benzene
Refined oils
Refined kerosene
Lamps
Stoves
Motors
Signal oil
Railroad signal oil
Lighthouse oil
Mineral seal oil
Coach and ship illuminants
Gas absorption oils
Intermediate Distillates
Gas oil
Carburetion of water gas
Metallurgical fuels
Cracking into gasoline
Diesel fuel oil
Absorber oil
Gasoline recovery
Benzol recovery
Heavy Distillates
White oils
Technical
Bakers machinery oil
Candymakers oil
Fruit packers oil
Egg packers oil
Slab oil
Medicinal
Internal use
Salves
External use
Creams
Ointments
Saturating oils
Wool oils
Twine oils
Technical heavy oil
Emulsifying oils—cutting oils
Electrical oils
Transformer oils
Switch oils
Flotation oils
Metal recovery processes
Still wax—wax tailings—roofing material
Candymakers wax
Wax
Candle wax
Detergent wax
Laundry wax
Iron wax
Sealing wax
Etchers wax
Cardboard wax
Saturating wax
Match wax
Chewing gum wax
Paper wax
Lubricating oil
Light spindle oils
Compressor oils
Ice machine oils
Journal oils
Motor oils
Steam cylinder oils
Compounded oils—water soluble oils
Valve oils
Turbine oils
Transmission oils
Railroad oils
Black oils
Grease compounding oils—compounded greases (for general lubrication)
Grease
Petrolatum
Medicinal
Compounded products
Salves, cream and ointments
Petroleum jelly
Technical
Metal coating
Lubricants
Gear grease
Switch grease
Cup grease
Residues
Residual fuel oil
Boiler fuel
Gas manufacture
Pitches and road oils
Oxidized asphalts
Steam reduced asphalts
Roofing
Paving
Felt saturating
Briquetting
Rubber making
Plastic composition
Coke
Carbon brushes
Carbon electrodes
Fuel
Acid coke
Fuel
Sulphonic acid
Saponification agents

in Chart 1, while those obtained from treatment of coal are shown in Chart 2. Each of these raw materials is the source of a long series of most useful and salable products.

The distillers of petroleum have found it worthwhile to go

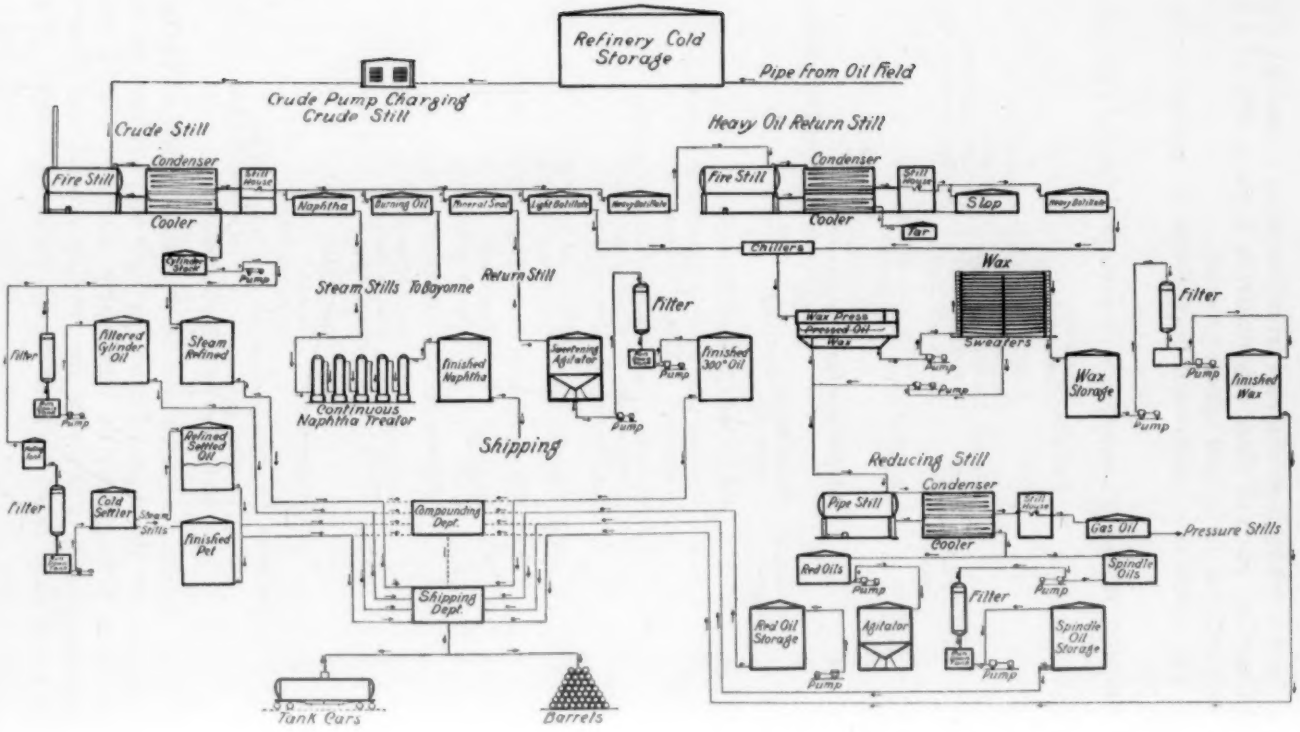
CHART 2.

Principal Products of Low-temperature Distillation of Coal and Their Uses.

- Coal
  - Hydrocarbon Gases
    - Fuel gas: Domestic; Industrial.
    - Alcohols: Ethyl, Isopropyl, Secondary butyl, Secondary amyl, Secondary hexyl → Solvents for Lacquers, Automobile paints, Artificial leather, etc.
    - Liquefied gases: Metal cutting; Illumination.
    - Motor fuel (Benzene): Automobiles, Solvents, Dyers' and cleaners' benzene.
  - Ammoniacal Liquor
    - Sulphate of Ammonia → Fertilizer.
  - Crude Oil
    - Motor fuel (Benzene) (as above).
    - Carbolic acid, Phenols → Plastics—Bakelite, Explosives, Dyes; Medical compounds.
    - Cresols ..... Disinfectants, Antiseptics.
    - Creosote oil ..... Wood preservative.
    - Lubricating oil .. General purposes.
    - Gas oil ..... Enriching water gas; Cracking to benzene.
    - Diesel engine oil . Internal combustion engines.
    - Fuel oil ..... Boiler fuel; Gas manufacture.
    - Paraffin wax .... General purposes.
    - Heavy tar, Pitch ..... Roofing material; Paving material; Briquettes.
  - Semi-coke
    - Boiler fuel ..... Hand fired; Stokers; Pulverized fuel.
    - Fuel for producer gas and water gas: Industrial gas; Domestic fuel gas.
    - Briquettes and other domestic fuel.

very far in their research and in the development of perfected apparatus for the separation of the various petroleum products and their preparations as marketable articles. Fig. 1 shows diagrammatically a chart of the refining process and illustrates the many steps taken to produce the various products. Fig. 2

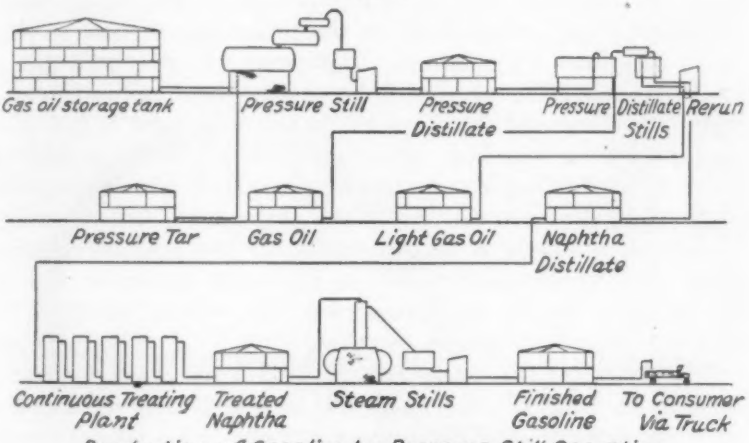
FIG. 1.


Refinery Cold Storage
Pipe from Oil Field
Crude Pump Charging Crude Still
Crude Still
Condenser
Fire Still
Cooler
Naphtha
Burning Oil
Mineral Seal
Light Bobillets
Heavy Bobillets
Heavy Oil Return Still
Slop
Tar
Chillers
Wax
Steam Stills To Bayonne
Return Still
Filter
Pump
Filtered Cylinder Oil
Steam Refined
Continuous Naphtha Treater
Finished Naphtha
Shipping
Finished 300° Oil
Wax Press
Pressed Oil
Sweaters
Wax Storage
Finished Wax
Refined Settled Oil
Cold Settler
Steam Stills
Finished Pet
Compounding Dept.
Shipping Dept.
Reducing Still
Pipe Still
Gas Oil
Pressure Stills
Red Oils
Spindle Oils
Red Oil Storage
Agitator
Spindle Oil Storage
Tank Cars
Barrels

is a flow sheet of a modern gasoline plant and shows that in the manufacture of this one product, elaborate apparatus and equipment are necessary. Obviously many other chemicals listed as products of petroleum are derived from the secondary products by further manufacturing processes, some of which are highly refined and technical.

Much research work is constantly being carried on by the great oil companies and new products, valuable in the arts, such

FIG. 2.



Production of Gasoline by Pressure Still Operation

as the long list of alcohols made from petroleum, show some of the results of this work.

(This is not intended, of course, to be a drawing of a refinery, but is supposed to be a sort of sheet showing in diagrammatic form the many, many steps that are taken from the original tank of crude petroleum at the top down to the tanks and other receptacles containing the finished products of the bodies. Do any of you gentlemen know any similar class of research, any similar quantity or volume or skill or investment, put into the investigation of the production of coal or improving the usefulness or form of coal such as we find in any of the great oil companies to-day? I think not.)

What is the reason that in the utilization of petroleum it has been so completely separated into widely differing fractions and products, each one best suited to its particular use, whereas coal

is still very largely used in its raw state? In the production of power from coal nearly all the research and invention has been directed to its more efficient use in its raw state, rather than in an endeavor to improve the form value of the coal itself and by treatment, similar in general to the fractionation of petroleum, to so separate the various constituents of the coal as to obtain the greatest total value.

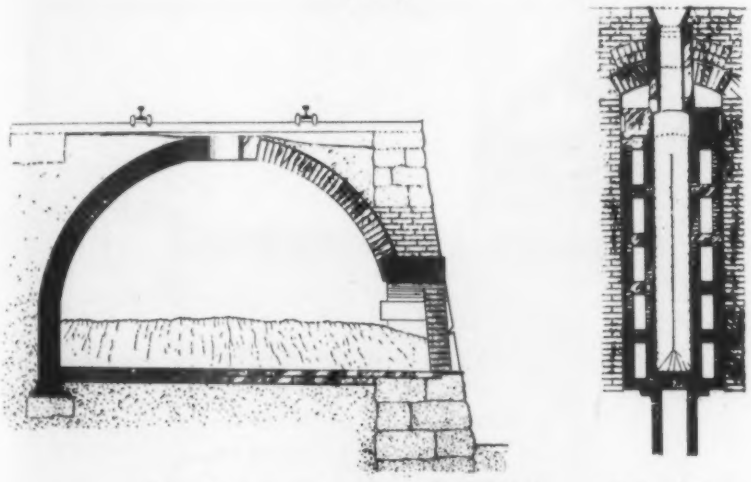
A prominent power engineer expressed recently in public a point of view which illustrates the attitude of mind of those who have concentrated on developing highly efficient methods of handling and burning, rather than on the processing of coal so that the most values are obtained. His point of view was that a B.T.U. is a B.T.U., whether it be obtained and utilized in one form or another and the thing the power men need is B.T.U's. Consequently he saw little advantage in any processing of coal or any attempt to improve its form value. It should require little argument to demonstrate that in the employment of any utility the aim to be sought is the production of the greatest ultimate value. We would surely make an important economic step, if by processing coal in an efficient way the form value could be improved or bodies could be extracted from it of sufficient value to more than pay for the processing, leaving as residue a better fuel than the original coal. This has been brilliantly done in the petroleum industry and the success attained is an inspiration to the coal engineer. It then remains to determine what products can be obtained from the raw coal, what are the best processes and how far shall the processing be carried to attain these greater values.

Although a very large percentage of coal is still used in its raw state, much has been done in several lines to increase its form value. One of the most important processes is the coke oven. It is some 250 years since the first coal was coked for producing a metallurgical fuel, but only in comparatively recent years has this coking process been carried on in an economical manner. The beehive oven was for many years the only means of making coke. The process produced from some coals an excellent coke well adapted for metallurgical uses, but the coals had to be selected with care and only a few produced satisfactory coke. In this country, for example, the Connellsville coal field reigned supreme for many years and Connellsville coke was the

standard. Hardly any other of the widely distributed and high-grade coals of this country could equal the Connellsville coal in the production of metallurgical coke by the beehive process.

In England the Durham coal field stood equally high. In 1893 the first retort oven, or as it is commonly called the "by-product oven," was introduced into the United States. The difference in principle employed in the two processes is illustrated in Fig. 3. While in the beehive oven the air was admitted

FIG. 3.

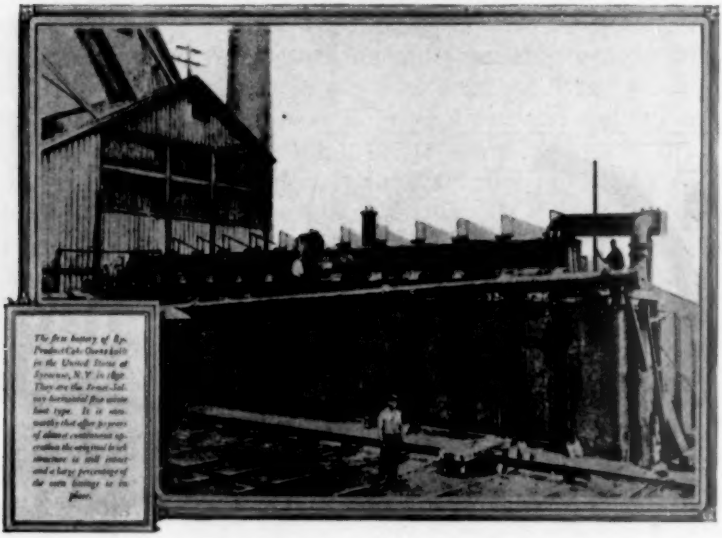


over the top of the coal and all the volatile matter and part of the fixed carbon was consumed in the coking process, the retort oven is a closed chamber heated from the outside and with its introduction we had for the first time a true distillation of coal on a commercial scale.

(I think you are all familiar with the difference in principle; this beehive being the process in which the air for burning the coal is introduced at the door to the right, and the gases were all burned in the overchamber, the heat passing through as shown by the cracks, and finally reaching to the bottom. In this other case, it is a true distillation with the heat applied through the walls of the retort into the coal, and the gases not being burned but passing out simply as distilled gases at the top. You are probably familiar with that.)

(The first plant of by-product coke ovens erected in this country was started in 1893, which is thirty-three years ago, nearly, and I don't think that it could have been called a commercial success in a broad sense for at least ten years thereafter. So I think perhaps the history of the by-product coke oven in this country, although by no means an untried process when it was brought here, may offer some encouragement to those of us

FIG. 4.



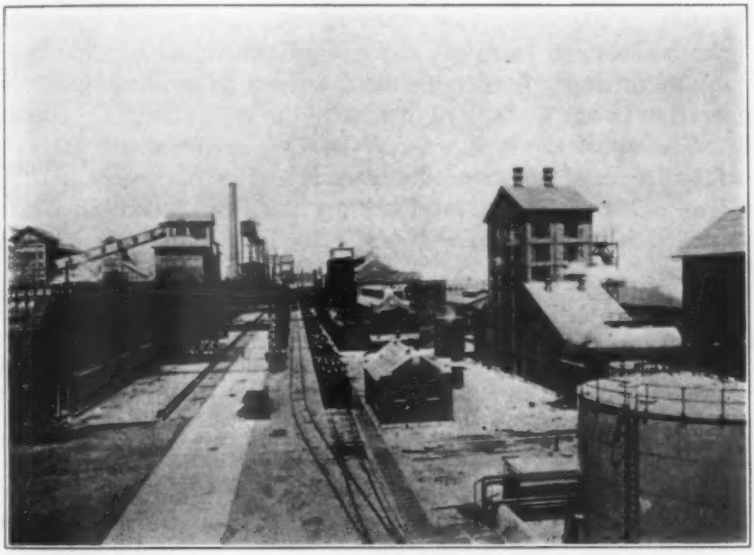
First American by-product coke ovens.

who have been working very hard, as some of us have, on methods to develop other processes for giving varied form value to coal.)

This consisted of twelve ovens, each having a capacity of 4.4 tons of coal per day. When this first plant was increased to twenty-five ovens having a capacity of 110 tons per day, it was thought that this was the most economical unit for the efficient employment of the labor and apparatus. At the present time units having a capacity of from 1500 to 1600 tons per day require practically the same crew as the first twenty-five and the several products produced are in every respect superior. Figs. 4 and 5 give evidence of the progress that has been made in the coking industry.

In the early days of the steel industry raw coal was the universal fuel for the steel furnaces, but the introduction of the gas producer, which was invented in its first form by Siemens, permitted the steel maker to use his fuel in the gaseous form, giving him much better control of his operations and greatly increased fuel economy. Gas producers have been wonderfully improved

FIG. 5.



Modern by-product coke oven plant.

since the days of Siemens, so that now almost all the work is performed mechanically.

The Mond producer was the next step; in this apparatus large quantities of steam were used to control the temperature of the fuel bed, so that with certain coals as much as eighty or ninety pounds of sulphate of ammonia were recovered per ton of coal gasified, in addition to the producer gas. In this type of producer the gas was delivered cold, so that it could be carried considerable distances without trouble from soot deposits and loss of sensible heat in the pipes. In England, Mond gas has been distributed from central plants to nearby localities for furnaces and other apparatus using gas, with considerable success. The Mond process has been introduced in this country in two or three

plants, but our coals are not so well adapted to this process as the English coals. It might appear that the loss of the sensible heat in the gas due to its being cooled and scrubbed for removing the ammonia and tar is a serious loss of efficiency, but it is claimed by one engineer of high standing who has made a special study of this point, that when the cold producer gas is burned in efficient regenerative furnaces the greater efficiency of the regenerators and the removal of the moisture usually carried makes the cold gas quite as efficient a fuel when figured back to the raw coal, as can be obtained from gas containing its original sensible heat. Frequent attempts have been made to utilize producer gas for generating power by burning it directly under boilers. Of course the efficiency of the gas as a fuel is high as compared with raw coal, but the cost of the producer plant and its operation and the loss of efficiency in the producer itself at least counterbalances the superior efficiency of the gas in the combustion chamber of the boiler.

The power user naturally thinks of the gas engine in this connection. This form of prime mover was a lusty youth some years ago, especially in continental Europe, but the successful introduction of the steam turbine has stopped its growth, at least for the present.

The great development of the processes of distilling petroleum in order to produce from the crude oil a series of more valuable products naturally suggests the employment of similar methods in obtaining a better utilization of coal. To what extent is this practicable?

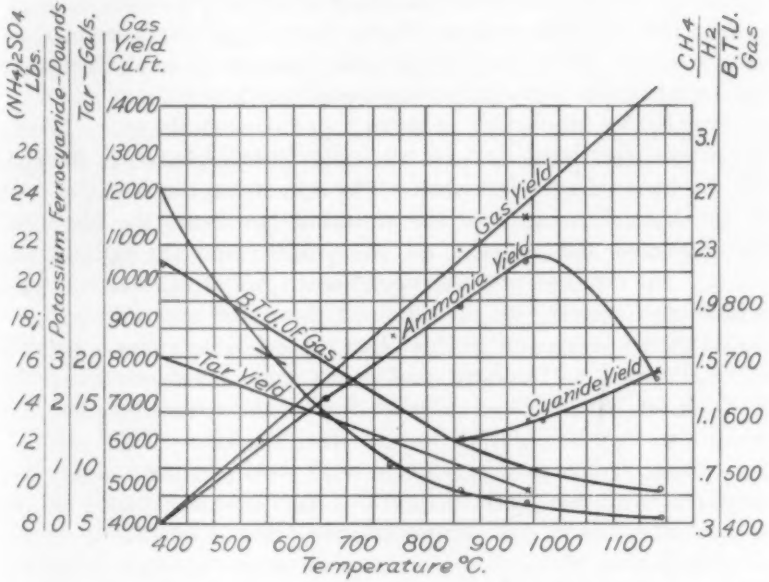
The general subject of coal distillation has been divided into two parts, namely, distillation at high temperatures and at low temperatures, the former field being occupied by the coking industry.

Processes for producing high-temperature coke have been developed so greatly, especially in recent years, that it would appear that there is little remaining to be done except in the refinement of detail. This art is probably so familiar to us all that we need not discuss it here. The distillation of coal at low temperature is, however, in quite another condition. Low-temperature distillation of coal may be defined as a process in which the hydrocarbons of the coal are driven off at temperatures sufficiently low, so that the primary products of the distillation

are not broken down or cracked by temperat
the operation. However, many of the so-called ive
ture " processes are carried on at temperatures above this limit.

In high-temperature distillation the hydrocarbons are broken down to a large extent, with the production of gas from say 10,000 to 13,000 feet per ton of coal, averaging from 550 to 600 B.T.U's per cubic foot. From eight to twelve gallons of coal-tar are produced, of the typical viscous composition con-

CHART 3.



taining much anthracene, naphthalene and other bodies of the aromatic series. Also from twenty to twenty-five pounds of sulphate of ammonia and about three gallons of crude benzol. The carbonaceous residue is a true coke with a hard and well-developed cell structure due to the forcing out of the coke body the last of the contained gases just as the high temperatures applied are hardening the coke from the viscous to the solid state.

(Chart 3 shows the effect of increasing temperature on the distillation products. This shows what we might expect in ratios at least from low-temperature distillation, and you know what happens as the temperature rises towards the standard heats used in ordinary high-temperature work.)

High-temperature carbonization has not offered much to the users of power. High-temperature coke was originally made to supply a more suitable fuel for metallurgical operations. The introduction of the by-product oven added tar and gas as possible fuels and these are now largely used in metallurgical work. Coke-oven gas has been found to be one of the very best fuels for the open-hearth steel furnace when properly employed.

(That statement I quote from a very prominent open hearth engineer in the Pittsburgh district, and it reminds me of a corresponding statement which was made by equally prominent engineers after an exhaustive test in the early days of the by-product coke oven in which they found after months of work that coke gas could not be used in heating open-hearth steel.)

Tar is also used either alone or together with the gas. In one important steel plant, at least, the only fuel purchased is the coal for the by-product coke ovens. The coke from the ovens is used in the blast furnaces and the resulting gas heats the blast for the furnaces and supplies all the power used throughout the plant. All the fuel for the open-hearth furnaces, soaking pits, reheating furnaces, etc., is obtained from the gas and tar produced at the ovens and in this plant there is just about a balance of requirements. In many steel works it has been found that the gas and tar have greater value as fuel in these metallurgical furnaces than can be obtained in any other market.

(Some of the most prominent steel works in the country had contracts with the manufacturers of tar products, based on the cost of tar, but in one particular case I know of in one of the largest plants, no tar was ever moved from the plant after the first year. Ever since then it has been used and all of it used in the steel works.)

The development of high-temperature distillation in the coke oven has given us an efficient process for manufacturing City gas as a primary product and there are many coke plants already in operation in connection with City gas plants supplementing or replacing water gas and the old horizontal gas retort. These plants are much more flexible in operation than the older coke plants and where there is a sufficient market for domestic coke, gas can be produced at very low cost.

(Before leaving this part of the subject, I want to show one more effort which is, I think, still not entirely complete. This is

one program for the complete gasification of coal. That, as you know, has been something which has been striven for by gas engineers for several years. And the firm which is responsible for that is very persistent and able in its efforts, but they have not yet reached complete success. The idea, of course, is to first distill the coal and then make gas out of the coke, or the carbonaceous product, and mix them together and still maintain a sufficiently high caloric value so the gas may be distributed without considerable expense; but that has not been a success as yet.)

The coke oven's most direct contribution to the power field is perhaps the production of motor benzol. The present rate of production is about one hundred million gallons annually. On account of its superior efficiency as a motor fuel, this is equivalent to from one hundred and fifteen to one hundred and twenty million gallons of gasoline.

This is, of course, a small percentage of our gasoline consumption, about one gallon of benzol to a barrel of gasoline, but on account of its superior value as a motor fuel, its influence in that field is greater than is indicated by this ratio.

(I had some practical experience in introducing benzoline in the earlier days as a motor fuel, and so it is a satisfaction to me sometimes when I remember the criticisms we used to get on benzoline to hear that a certain mixture or combination is "almost as good as benzol for a motor fuel.")

But, excepting the benzol, none of the high-temperature products are of important interest to the power user. He has made great improvements in the mechanical handling of fuel for power purposes, powdered coal secures important economies for some installations and the mechanical handling of the fuel in various types of stokers reduces labor cost and increases efficiency of combustion.

Will the distillation of coal at low temperatures, about which so much has been written of late, give to the power user a processed fuel which can be used advantageously? In Germany the answer appears to be clearly in the affirmative. Their principal supplies of coal are of inferior quality as compared with American coals. The oils produced by the distillation of the coal have higher values than ours on account of the greater cost of the competing petroleum oils. How far can the Americans follow what the Germans have done and which of the many processes

that are now in the experimental stage can be worked out to the advantage of the American power user?

True low-temperature distillation produces quite a different set of bodies from those obtained in high-temperature coking. About half as much gas is produced with a value of perhaps 750 to 850 B.T.U's per foot.

Naturally the yield of tar is correspondingly increased, up to from twenty to thirty gallons, depending upon the process and temperatures employed; the tar is quite different in composition, much less viscous and contains larger percentages of unsaturated hydrocarbons, chiefly of the paraffin and olefine series. It is essentially high in tar acids but not in phenol, and it now presents an interesting problem to the tar distillers as to what field of usefulness it will occupy. The carbonaceous residue is unformed, usually without a real cell structure, its physical condition depending upon the process employed.

The distillation of coal at low temperatures can hardly be said to have passed out of the experimental stage, but especially from the point of view of the power user it is of the greatest potential interest.

If a process can be worked out wherein the plant can be built and operated at low cost and from which the oil and gas can bring returns sufficiently to cover the costs of capital charges and distillation, the power user has available the char for a carbonaceous residue which should have advantages for power production superior to the raw coal in several respects. This char may be produced in pulverulent form as in one process now being tried out, or it may be delivered to the stoker in red-hot condition ready for prompt combustion on almost any of the present types of stokers. Such a fuel can be burned with accurately proportioned air and should insure uniform and economic firing.

There are many coals in this country which would be greatly benefited by this preliminary processing. Whether there would be advantage when the very best coals are available remains to be shown. It is easier to see a benefit in the high oxygen coals of our middle states and farther west. With such coals the results obtained in the German plants might be duplicated when the proper carbonizing process has been developed.

Of course the commercial value to the power user of any

system of coal processing depends to a large extent upon the returns that can be realized from the by-products.

The British Fuel Research Board has found that low-temperature tar when dehydrated and freed from solid matter is an entirely suitable fuel for Diesel engines.

Laboratory experiments have shown that when cracked under proper conditions a good yield of motor fuel is produced. Its high percentage of tar acids suggests special value for this oil as a source of preservatives and disinfectants. But the highest values for these oils cannot be determined until they are available in commercial quantities. At present they can in general be given only equal market values to petroleum fuel oil.

If we are to gain by the processing of coal anything like the great advantages which are suggested by similar work done in the petroleum industry, it appears that we must look to some efficient process for the low-temperature distillation of the raw coal for the solution of the problem. As in any new industry much experimental work must be done, many mistakes made, with many failures. The improvements made in recent processes seem to offer hope that some of them will succeed in effecting the improvement in form value of this raw material to the advantage not only of the power user, but to the other industries into which these several products will naturally go.

Elimination of Salt from Sea-water Ice. W. G. WHITMAN. (*Am. Jour. Science,* Feb., 1926.)—Two years ago Dr. V. Stefansson suggested to the Department of Chemical Engineering, M.I.T., the investigation of the process by which sea-water ice loses its salt. In his book, "The Friendly Arctic," he says that such ice a few days old cannot be used for cooking or drinking purposes. Ice that has floated for a season in the ocean provides water that can be drunk though brackish, "while ice that has been floating for two or three seasons contains less salt than ordinary river waters."

An individual crystal of ice frozen from brine contains no salt in general. The saltiness of a mass of ice is due to the brine entrapped between the crystals of pure ice. Let a quantity of 4 per cent. brine at 32° F. be cooled down. All of it remains liquid until 27.5° F. is reached, at which temperature pure ice begins to form. The abstraction of a part of the water to form ice increases the concentration of the residual brine. As the temperature falls more ice separates and the concentration of the brine continues to increase. At 0° F., for example, it will contain 20 per cent. salt. At –6° F. all the brine left freezes, giving eutectic crystals that have a 22.4 per

cent. salt content. The pure ice crystals previously formed, of course, are also in the resulting mass. Reduction of temperature below the eutectic point produces no change in composition. Elevation of temperature causes no composition change until –6° is attained, when the eutectic crystals melt. As heat is further applied, crystals of pure ice melt until above 27.5° only liquid remains.

A drop of brine is surrounded by crystals of pure ice. To stay in equilibrium with the adjacent ice, the brine must have a certain concentration depending on the temperature. If the brine is too weak, ice will separate until the residual brine has the right concentration for equilibrium. If, on the other hand, it is too strong, some of the ice will melt and dilute it to the required strength. Suppose, further, that there is a difference of temperature between the ends of the block of ice containing the drop, and that the concentration of the brine forming the drop is just right for equilibrium at its middle section. Then toward the warmer side of the block the drop is too concentrated, and to restore equilibrium a little ice will melt, producing dilution. Toward the cooler side of the block the drop is too dilute and ice forms, thus raising the concentration. The net result of melting on the warm side and freezing on the cold side is to shove the drop bodily forward toward the warm end. The drop thus works its way toward the warm end, growing more and more dilute as it proceeds. If salt gets out of sea-ice in this manner, liquid drops must be present in the ice. This cannot be the case below –6° F., the eutectic temperature.

To test these deductions by experiment cylinders of salt-ice were prepared by freezing brine containing 3.3 per cent. NaCl. Analysis of five sections of the cylinder showed that the salt was uniformly distributed. The bottom of such an ice cylinder was kept for five and a half hours below 0°, while the top had a temperature of from 21° to 32° F. Then the ice was cut into five parts by horizontal sections and the parts were analyzed. The NaCl content was 2.92 per cent. in the lowest and 3.88 per cent. in the highest. It will be noted that the salt migrated upward against the force of gravity, even though the brine drops were denser than the ice around them. In another arrangement simulating more closely the condition of ice in a polar sea the upper end of the ice was kept at –13°, while its lower end was in brine at 25° F. Under these conditions the lowest part of the ice after six and a half hours contained 2.5 per cent. NaCl and the highest part 1.86 per cent. It thus appears that the drops of brine travel toward the warmer part of the ice, no matter whether this requires an upward or a downward motion. Experiments made below the eutectic temperature where no liquid could have been present gave no indication of migration of the salt through the solid ice. The rate of diffusion under the conditions of the laboratory was probably greater than in nature, where at one season of the year the upper face of the ice is the warmer while in winter the opposite is true. G. F. S.

LOW-TEMPERATURE CARBONIZATION.*

BY

V. Z. CARACRISTI.

COMMERCIALLY, there exists a clear line of demarcation between the art of so-called "high-temperature distillation" and the art of "low-temperature distillation." This line is the basic difference in character of the solid residues recovered.

The object of a high-temperature distillation plant is to make metallurgical coke, whereas the object of a low-temperature distillation plant is to recover the gaseous and liquid hydrocarbons.

Coincidently with the conversion of coal into metallurgical coke through the modern indirectly heated oven, an opportunity is afforded for the recovery of a certain percentage of the volatiles in the form of gaseous and liquid hydrocarbons. When all the factors are taken into consideration, however, the net value of the coke produced as compared with the net value of the by-products shows an overwhelming preponderance in favor of the coke. Therefore the hydrocarbons and nitrogen recovered are properly considered by-products.

In low-temperature distillation plants, the comparative values of the solid residue and the recovered hydrocarbons show a reversal, in contrast with high-temperature practice, the by-product becoming the low-temperature coke recovered.

It should be remembered that this material is not a commercial coke, lacking the structural strength to permit its use, for metallurgical purposes or directly as a fuel, in the form in which it leaves the oven.

This wide variance in primary object, together with the fact that the equipment necessary in the two processes of heat treatment is radically different, removes the possibility of any controversial question between the two arts. Each has its function and its limitations. The function of the high-temperature oven is to make a coke of high structural strength, and its limitations

* Presented at a joint meeting of The Franklin Institute, the Engineers' Club, the American Society of Mechanical Engineers, Philadelphia Section, and the American Chemical Society, Philadelphia Chapter, held Friday, April 23, 1926, in celebration of Oil and Gas Power Week.

lie in the chemical and physical properties of the raw coal suitable for such use, as to resin, ash, and volatile contents. The function of a low-temperature distillation oven, on the contrary, is to make gas, oils, and tars, and its limitations lie only in the amount of volatiles or distillates available. The selection of the material to be treated, economically, has been reduced to the relation between coal treated and volatiles recoverable. The preponderance of commercial value lying in the recoverable liquid or gaseous hydrocarbons, and their relation to the coal treated, is therefore the governing factor in low-temperature plants.

Low-temperature results, insofar as character and commercial value of the condensables are concerned, are affected largely by the temperatures to which the gases as distilled are subjected while under treatment. High-temperature zones of localized heat effect should be religiously avoided, if the maximum value is to be expected from the recovered hydrocarbons. Great care should be taken to prevent infiltration of air, with its contained oxygen, while the gases are in the unstable condition due to high-heat effect. Localized heat has the effect of breaking down the hydrocarbons and releasing the carbon contents, resulting not only in economic loss, but also in the formation of amorphous carbon deposits detrimental to continuous operation. The effect of the admission of oxygen to the gases is the destruction of those unstable hydrocarbons having a higher commercial value, and their conversion into tar acids.

A review of the published data on low-temperature distillation brings out the fact that its development has largely followed the development of metallurgical coke plants, the inception of which was the beehive oven, in which the destruction of the unstable hydrocarbons through combustion is used to generate the heat required to drive off the excess volatiles and to create the temperature and pressure conditions necessary for the formation of a structurally strong coke. Since the commercial development by Coppee in which advantage was taken of indirect heat, and which eliminated the admission of oxygen to the coal under heat treatment, thereby permitting the removal and recovery of the hydrocarbons in virtually their primary state, no serious consideration is now given to the destructive method of internal heating when applied to metallurgical coke manufacture.

There can be no question as to the relative commercial advan-

tages of the modern high-temperature coke oven as compared with the early form of beehive oven, and any attempt to parallel the operation of the obsolete beehive oven in low-temperature plants—regardless of structural modifications—can only result in the duplication of beehive oven results, that is, the recovery of coke alone in commercial quantities.

If the recovery of coke was the primary object of low-temperature plants, the use of a modified form of beehive oven, or even the modern high-temperature oven, might produce commercial returns without the necessity for any pioneer development. However, the value of the coke is negligible, and its production merely incidental in the treatment of coal for the specific purpose of securing, in primary form, the volatiles available in the raw material.

The essential factor in low-temperature distillation is, therefore, the treatment, under low-heat conditions, of the maximum amount of material, irrespective of the character of the by-product coke rejected. For instance, a low-temperature plant for the treatment of shale might be entirely successful from a commercial standpoint, although in such treatment the disposal of the residue would entail an expense rather than represent a source of potential revenue.

Although basically the process of low-temperature distillation is simple, the reduction to practice in commercial installation introduces complications of the most serious character. These are briefly summarized as follows:

(1) The necessity for large tonnage throughout, per unit of time and cost.

(2) Low-heat head conductivity of coal in mass.

(3) The difficulty of constructing an apparatus in which heat losses are minimized to a point where heat input is not prohibitive.

(4) The formation of gases condensing into sticky resins or tars even at relatively high temperatures.

The first and second difficulties practically eliminate from consideration a structure similar in design to a high-temperature oven of either the beehive or modern type, for the reason that low-temperature distillation is essentially that produced at low-heat head, and unless this condition is maintained the effect will be that of high-temperature distillation.

In low-temperature distillation the entire structure utilized for

distillation purposes must be kept under a heat condition which will prevent secondary cracking of the volatiles (due to passing through a higher heat zone) after their primary distillation in the structure, and prevent their condensation and redistillation, as would be produced when these gases pass from the point of their origin into a cooler zone in the mass, causing them to be progressively redistilled up to the time the entire mass has reached a uniform temperature condition necessary for low-temperature results.

The only effective heat is that which enters into the material under treatment. The losses due to radiation are of great importance, but can be compensated for by a reduction in the time element. The low-heat head necessary for low-temperature distillation of coal in mass may necessitate an increase in time element to a point where the radiation losses involve an input of heat per unit of output of product which will destroy the possibility of even reasonable commercial results.

It may be said that this difficulty is the dominating problem in low-temperature work. Such heat losses, despite the fact that the values of the recovered by-products are liberal, may reach a point beyond which the cost of the heat input is greater than the value of the recovered products.

The difficulty due to condensation of gases into sticky resins or tars, even at relatively high temperatures, creates an operating condition difficult to overcome in commercial practice. Although this tendency is inherent in the majority of coals, some coals and lignites are free from the tendency, under the temperatures necessary for low-temperature distillation, and therefore the commercial treatment of such material is greatly simplified. The effect of this sticky condition in the majority of coals is so great as to convert even the material itself when under treatment to almost liquid form. This is largely responsible for low-heat conductivity, and exists until the mass of material under treatment has entirely been freed from hydrocarbon matter of this character.

The following operating description of one installation in which the complications of reduction to practice have been overcome to a degree of commercial utility, may be of interest.

The effect on commercial output of low-heat conductivity of coal in mass is avoided by distilling the coal in a thin layer, so as to reduce the insulating head to a minimum. It has been found

that a coal layer approximately one-half inch thick best meets the requirements of the time element, the output being the product of time multiplied by mass. As an example, the time element for the reduction of the volatile from 35 per cent. to 12 per cent., with an insulating head of one-half inch, will approximate three and one-half minutes when the initial temperature head of 1200° F. is used. If the thickness is increased to one inch, the time element to secure equal results will approximate twelve minutes. The half-inch layer gives approximately seventeen turnovers per hour, as compared with five turnovers per hour for the one-inch layer, or on a relative weight basis of eight and one-half to five, in favor of the half-inch layer. This ratio spreads even more widely in favor of the thinner layer as the thickness increases.

A large output per unit of time has a direct influence in overcoming the difficulty of constructing an apparatus in which heat losses per unit of output are minimized, and through the construction of an internally heated apparatus wherein the heat input has been concentrated at the point of use, this heat is directly transferred for the purpose of converting the hydrocarbons into gaseous form, the losses being limited to those non-recoverable on account of the heat necessary for this conversion, plus the recoverable losses incident to the heat removed by the gases when leaving the structure, plus the heat losses incident to the removal of the residue at approximately 500° F. less than the distillation temperature. These recoverable and non-recoverable heat losses include the losses of efficiency of the heating medium, reducing the heat input necessary to less than 1000 B.t.u. per pound of coal treated. An analysis of this heat input indicates an efficiency within 5 per cent. of that theoretically possible.

In order to obtain these results it was necessary to resort to recuperation of the heat in the spent gases, and the partial utilization of the heat in the by-product coke.

The difficulties due to the formation of sticky resins or tars have been overcome through the use of moving surfaces, in relation to which the coal under treatment is stationary. It is of course understood that the sticky properties of any material in the process of distillation disappear with the volatile. No material treated so far has been found to be of sticky character when the volatile content of the treated mass is reduced to less than 15 per cent. Below this point the material has no tendency to

adhere to either moving or stationary surfaces with which it comes in contact. It must be remembered, however, that this percentage does not represent an average condition, but must be the maximum at any point.

As in any heat treatment, the progress of the heat zone begins at the point of application and gradually works its way through. It only requires a few seconds for that portion of the mass in intimate contact with the heating element to have its volatile driven down to a point beyond which the heat will not become effective. Immediately over this point of contact, however, will be a zone of only partial distillation. The heat penetration into the mass of the material is much simplified if secondary condensation does not take place, as in lignites and other materials which do not, in themselves, form a seal through the condensation of the material within or on the surface of the mass.

The time element given in preceding paragraphs is for coals which, through change in physical characteristics, form a seal and in which the time element of heat penetration is the maximum. Under similar heat conditions, materials of a non-coking character can be treated within less time.

The method of transfer of the heat to the material under treatment is of prime importance. At the low-temperatures required for this process, the heat transfer by radiation is extremely slow, decreasing as the fourth power of the total heat head. The heat transfer rate, however, through solid bodies, is not so materially affected by temperature head. Therefore intimate metal-to-metal contact from the source of heat to the point of use is of great importance. This contact is best obtained by the use of a liquid in which is submerged the heating element, and on which is floated, partially submerged, the heat transfer element, which in turn, through physical contact, supports the material under treatment.

Usually the exothermic properties of material not containing sticky resins or similar hydrocarbons, such as lignites and sawdust, are of value in reducing the heat input. On the other hand, such properties have a detrimental effect on the product, through the increase in tar acid formation, and a decrease in the B.t.u. value of the fixed gases driven off.

Although good thermal efficiency permits the recovery of an actual surplus of fixed gas, economically the use of the gas

primarily distilled from coal is a waste, and it is much more advantageous to use the residue, or coke, after the removal of volatile hydrocarbons, as a heating medium, which can be done most satisfactorily through destructive distillation.

The surplus of low B.t.u. gas made available in this way is very valuable in reaching the B.t.u. value of the fixed gas produced to the commercial requirement of approximately 500 B.t.u. per cubic foot.

The amount of heat available in the form of fixed gas varies with the character of the hydrocarbon volatiles driven off, some coals, for reasons not completely analyzed, containing over five million B.t.u. per ton of fixed gas, and others of approximately the same volatile content containing as low as three million B.t.u. per ton in fixed gas. The B.t.u. of the gas after cleaning and scrubbing for liquid hydrocarbons uncondensable in the coolers, will vary from 775 to 960 B.t.u. per cubic foot. This range represents the minimum and maximum found in operation.

In order to conserve the value of the high B.t.u. gas it is advantageous to utilize the solid residue for the manufacture of low B.t.u. non-commercial gas as a heating medium, so that all of the high B.t.u. gas may be utilized for domestic or commercial purposes.

In some cases it will not be desirable to scrub the gas for liquid hydrocarbons uncondensable by cooling, for the reason that the heat value in gaseous form may have a considerably greater commercial value than in liquid form, particularly when the expense of the scrubbing has been added to the cost of the liquid. This condition, however, is governed entirely by the local relative values of the two forms of fuel.

The liquid hydrocarbons will vary inversely with the non-condensables, and in practice have been found to range from twenty to thirty-two gallons per ton of coal treated, without taking into consideration the liquid hydrocarbons recovered in oil scrubbing treatment of the coal gases, which latter will vary from two to four gallons per ton of coal.

The uses of the liquid hydrocarbons are too well known, and have been too thoroughly discussed by competent authorities to require consideration here. I may say, however, that the character of the general product known as low-temperature tar varies with the method of treatment and the amount of secondary crack-

ing to which the gases have been exposed after being driven off the coal. I believe that the liquid hydrocarbons obtained from the "Continuous" process are in themselves of peculiar character. This has been brought out by several years' research work on these tars.

In general, the tars from the true low-temperature process approach the chemical characteristics of a petroleum which has been subjected to a cracking process. It is a simple matter to subject the hydrocarbons, while in gaseous form, and away from the mass of coal under treatment, to any degree of heat necessary for further cracking, should this be found desirable.

In the handling of the solid residue tempering is a serious problem. All of the oxygen having been driven off in the heat treatment, as it leaves the oven the material is highly susceptible to spontaneous combustion through absorption of oxygen from the atmosphere. It cannot be piled or stored unless tempered, and in this respect has all the attributes of charcoal. It has been found, however, that disintegration in a beater type mill provides sufficient tempering for reasonable storage. If the disintegration is followed by pulverization, ample opportunity is given for the absorption of oxygen in sufficient quantity to prevent the building up of internal heat. The reason, of course, is that both processes involve the admission of a considerable amount of air, permitting slow oxidization to take place at a degree of temperature at which spontaneous combustion does not occur.

After crushing and pulverizing, the material is ready for further treatment. The simplest method of disposal of the residue and the recovery of its commercial value is through the conversion of its heat into steam and electric energy. For these purposes no further treatment is required, other than the use of an accepted type of pulverized fuel-burning apparatus. Several thousand tons of residue from a "Continuous" type low-temperature distillation plant have been successfully used in this way in "Lopulco" furnaces with extremely good thermal efficiencies. When this fuel is burned in suspension the character of the flame is practically ideal, as the fuel contains no tarry substances or other smoke-producing elements, and contains sufficient volatile to permit of complete combustion without special furnace design.

The physical appearance of the residue, after crushing and pulverizing, may be compared with a mass of microscopic bubbles.

Its specific gravity is much lower than that of coal when similarly treated.

The hydrocarbons remaining in the residue are of high B.t.u. value, approximating 25,000 B.t.u. per pound. This results in a net increase in the B.t.u. value per pound as compared with raw coal. The residue is relatively free from inert gases and very low in contained oxygen, which makes it an ideal fuel for conversion into useful work. In fact, as compared with raw coal, there is a marked increase in over-all efficiency of boilers fired with this material.

The residue may also be profitably disposed of in the form of briquettes. Although much work has been done on this method of converting the residue into a commercial fuel for domestic purposes, much remains to be done. The problem is a serious one, particularly when the tonnage of residue is considered. The briquetting process must not reintroduce tarry hydrocarbons which would affect the smokeless character of the residue. Briquettes must be oil-treated and baked, to permit of their reasonable handling and storage. After crediting the value of the liquid and gaseous hydrocarbons recovered, the cost of the residue is negligible, and considerable leeway may be allowed in the matter of expense for briquetting and if domestic fuel is the primary object of the operation, it would seem that briquetting offers the best solution of the problem of disposal of the residue.

Some effort has been made toward the conversion of the residue into a form suitable for direct use as a domestic fuel. As far as operation is concerned, this may be accomplished very simply by the mixture of a percentage of the treated material with raw coal before passing through the distillation plant. The cost is fairly high, however. The resulting product is not as dense as metallurgical coke, and to my mind does not represent a true commercial form. In addition, it is impossible to maintain the proper balance between the amount of treated material to be mixed with the raw material under treatment, and the total output.

In the making of metallurgical coke, the limitation as to volatile content necessary for a dense structure, with the minimum "breeze" loss, has been entirely overcome by using low-temperature coke in proportions of approximately 20 per cent. of coke to 80 per cent. of raw coal, varying with the volatile content

of the raw coal. Such a mixture gives an excellent metallurgical fuel. Only a small percentage of the coke residue from a low-temperature plant can be disposed of in this manner, owing to the relatively small amount of metallurgical coke used in proportion to the potential output of low-temperature plants.

Low-temperature coke also offers an ideal material for complete gasification. It has been tried out in producer plants and found to compare most favorably with other materials available. In fact, the high B.t.u. value of the remaining hydrocarbons, combined with the physical properties of the coke, are responsible for remarkably good results. Although to my knowledge the material has not been tested in water gas plants, it should be thoroughly suitable for this method of gasification, and the enriching oils of the liquid hydrocarbons, with the high B.t.u. gas, indicate that the fuel may be converted directly into a commercial gaseous product, without the addition of gas, oils, or other enriching media.

It should not be understood that the consummation of results, based on the broad statements of requirements outlined herein, was attained in the "Continuous" process, as at first conceived and designed. Owing to lack of precedent, commercial pioneering had to be undertaken which would have been impossible except for the support of Mr. Henry Ford.

To those contemplating similar pioneering, some of the difficulties we encountered, and the magnitude of their importance, may be of interest, and since open confession is good for the soul, I will attempt to explain a few of the more glaring deficiencies in the installations even after the expenditure of several million dollars, and to explain the methods used in the correction of these troubles.

The first difficulty was in the preliminary heating of the oven. Owing to lack of either producer or high B.t.u. gas the preliminary heating was undertaken with oil torches. The character of the structure was such that a careful check could not be kept on the temperature of the heating chambers, and a large number of the cast-iron flues, each of which represented more than a thousand dollars, developed cracks and leaks to such an extent as to finally necessitate the draining of the lead contents of the oven, and its rebuilding.

When close inspection was possible the cause of the failure of the flues was immediately apparent. It was found that the heating chambers had reached temperatures exceeding the melting-point of the refractories, and the iron in the flues had not been able to radiate heat sufficiently fast to prevent serious deterioration, ultimately resulting in complete failure.

Obviously some other method of heat application was necessary, in order to eliminate localized hot spots inside the furnace chamber, due to heat transfer through the refractory material into the chamber above the heating medium, as well as to apply the heat at a point where it could be radiated directly into the intermediary heating medium.

Relocation of the burner tips, and the simple reconstruction incident thereto eliminated the trouble, and the lesson learned was that the ideal, and only practical heating medium is gas, the flame temperatures of which can be readily controlled.

Next in order of appearance, but primary in importance, arose the difficulty of providing a feeding device which would deliver measured quantities of crushed coal at predetermined rates. The feeding apparatus originally designed functioned perfectly until the raw gases from the distillation chamber condensed within the mechanism of the feeder to such an extent that the dust incident to the handling of the coal within the mechanism built up and stopped the feed.

The substitution of steam under several millimetres more pressure than that maintained within the distillation chamber seemed to offer at least a partial answer to the problem. The steam removed the tarry substance satisfactorily, but condensed into water vapor which again permitted the dust to build up and choke the feeding apparatus.

The next step was the introduction of cool stripped gas from the oven itself, after passing through the cooling towers and scrubbers. This gas was entirely free from condensables, and was considered ideal for the purpose of creating a plus pressure condition which would prevent the raw gas and its tarry contents from entering the mechanism. Over this feeder was a head of coal of approximately forty feet, crushed to three-eighths inch and under, which was regarded as an ideal sealing medium. However, this coal did not provide such a seal, and it was necessary

to entirely scrap the feeding mechanism, and redesign and rebuild it.

Several experiments, expensive as to time and money, were undertaken before the ideal feeding arrangement was developed. This resolved itself into the simplest form of double reciprocating device, having a localized gas chamber not communicating with the main coal storage bunkers. The introduction of gas containing non-condensables into the small chamber of this feeder receiving the coal, reduced the gas losses almost to the minimum, and has proven the solution of the feeder difficulties.

In the return chamber of this oven, the plates denuded of their coal charge, or low-temperature coke, were designed to give up part of their remaining heat for the purpose of continuing the distillation process after the material had left the heat input zone. Owing to difficulties in feed and regulation of output due to the formation of " thick " spots through which the time element was not sufficient to permit the heat to thoroughly penetrate, a certain percentage of coke still in sticky form accumulated in this chamber, causing considerable difficulty. It was decided to eliminate the difficulty bodily rather than attempt to correct it. The removal of this portion of the device resulted in a reduction of tonnage output, but not to a degree where the commercial return was seriously jeopardized.

The growth in length brought about by an increase in the chain of plates on which distillation took place was improperly estimated, but this only necessitated the removal of some of these plates from the chain structure. In the structure as designed, it was impossible to compensate for this increase in the usual manner of slack adjustment, but this can be simply and satisfactorily worked out, in future installations.

The plates on which distillation is made leave the heating chamber at the full temperature of the heating chamber. After leaving the intermediary heating means they remain in a gaseous atmosphere, containing primary distillates subject to secondary cracking. This resulted in the gradual building up of amorphous carbon films on the useful side of these plates. On the surface side of the plates the carbon was progressively removed by the coal layer. On the under side, or that portion coming in contact with the heating medium, no friction action was present owing

to the zero resistance of the heating medium, and this carbon gradually built up to an appreciable extent, the rate of accumulation being about one thirty-second of an inch per week. Four or five weeks' accumulation of this carbon deposit acted as an insulating medium, causing a drop in output. This difficulty was entirely unanticipated, and its cause unknown, and it gave considerable anxiety, although its correction was very simple.

As in similar operations, considerable supervision is necessary. The material must not be allowed to leave the distillation plates until the entire mass has been distilled to less than 15 per cent. volatile. Defective feeding, and the creation of localized mounds, result in a product which contains enough sticky substance to build up, after several weeks, into masses which cause serious operating trouble.

Some of the troubles which our friends and critics anticipated, but which did not develop to any extent, warrant consideration.

The time element for distilling was within very close range of that estimated, for the various thicknesses. This was the natural result of careful preliminary work, in which the thicknesses and time elements were determined in a laboratory structure designed and operated under conditions identical with those of the commercial structure.

The difficulty of holding the bath of lead in a refractory structure was non-existent. Refractory blocks which had been for several months under a head of molten metal at full working temperature were entirely free from any evidence of lead infiltration except where mechanical defects existed, such as cracks, etc. No lead has been lost from these ovens, the cooling pipes being entirely effective in preventing such losses.

After change in the method of heat application, the cast-iron flues have remained 100 per cent. perfect, in spite of the fact that a number of these flues have been welded for blow and pinhole defects.

The recovery of the heat in the spent gases from the heating chambers has been entirely satisfactory, as evidenced by the low-heat input per unit of material treated.

The lead loss due to the passage of the chain of distillation plates through the lead bath has been negligible, being less than one pound of lead per ton of coal treated. A certain percentage

of this is recoverable. The primary loss is due to the pump action of the hinges in the distillation chain splashing lead on the plates or under side of the coal. The lead is recovered in the pulverizing mills, which are of the air-separation type, and the lead particles, unaffected by the air-blast, remain in the sludge chamber for periodical removal and recovery. The lead which adheres to the underside of the plates after leaving the lead bath is considerable, until the plates reach their temperature and the oxygen in the lead has been reduced through its absorption by the hydrocarbon gases, which have a higher affinity for oxygen than the lead. This lead is caught before coming in contact with the coke residue, and periodically drained into pigs for reintroduction into the heating chamber.

The practicability of the lead bath as a medium for the transfer of heat has been fully demonstrated. Its value as a heat storage reservoir is great, because it prevents momentary fluctuations in temperature in the distillation chamber or at the point of primary distillation.

As to the future of low-temperature distillation, there is little if any doubt as to its importance, from an economic standpoint, perhaps not so much in this country as in foreign countries not so generously blessed with natural liquid hydrocarbon deposits, and countries foreign to the United States will undoubtedly reach a stage of full development in low-temperature distillation work before we have awakened to its importance in the economic life of this country.

The burning of raw coal, or even coke in primary or metallurgical form, for domestic heating and similar purposes is wasteful, in my opinion, and the time can be foreseen when such methods will be entirely superseded by the more modern method of full utilization of heat energy in the form of gas and electricity.

The processing or manufacturing of coal and its by-products, and the conversion of its energy into power or gas, do not lend themselves to adaptation for isolated installations of small capacity. Neither is it imperative that the operation be carried on at the point of origin of the crude materials. The expense and losses due to transmission over long distances will more than balance the freight cost of conveying the raw material to centralized plants located at points where the expense and losses of long transmission to the ultimate consumer are minimized.

LOW-TEMPERATURE CARBONIZATION IN EUROPE AND AMERICA.*

BY

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ONE of the most fascinating studies in the realm of pure science to-day is that concerning the constitution of coals. Many engineers have the mistaken impression that coal is a mineral composed essentially of carbon, hydrogen, oxygen, nitrogen, sulphur, ash and water in varying proportions, having little appreciation of its conglomerate chemical nature, nor of its inclusion of many of the most complex structures known to organic chemistry. Franz Fischer, Director of the Kaiser Wilhelm Institute for Coal Research at Mulheim, says that while proximate and ultimate analyses are important both from the scientific and technical point of view, they tell us no more concerning the number and kinds of chemical compounds that constitute coal than the reader would learn of the contents of a book if told they consisted of 15 per cent. of the letter "e", 5 per cent. of the letter "n", 1 per cent. of the letter "g", 4 per cent. of the letter "b", etc. As the reader must have the grouping of letters into words and words into sentences, so the chemist must have the grouping of atoms into molecules and the proportion of each molecular compound in the coal aggregate before he acquires an adequate knowledge of the constitution of coal.

It is not within the scope of the present paper to dwell upon the many absorbingly interesting methods of attack upon this fascinating problem. Destructive distillation at varying temperatures, needless to say, is one of them. It was *via* this approach that the speaker first became interested in low-temperature distillation. Marked as it had been by an impressive record of failures, its eventual commercial application at that time seemed highly improbable. Later, while Fuel Engineer of the U. S. Bureau of Mines, it became his privilege to make a rather detailed study of

* Presented at a joint meeting of The Franklin Institute, the Engineers' Club, the American Society of Mechanical Engineers, Philadelphia Section, and the American Chemical Society, Philadelphia Chapter, held Friday, April 23, 1926, in celebration of Oil and Gas Power Week.

commercial attempts of this character, both in Europe and America. Thus it became possible to gather, glean and correlate much interesting data. For over a year after his return from Europe from such a study in 1924, he hesitated publishing this data from an inborn conservatism which indicated the possibilities almost too good to be true. It has only been within the past year that corroborative evidence so convincing in character has become available that the commercial future of low-temperature carbonization has seemed assured.

Realizing that there are wasted in the United States to-day, economically recoverable coal by-products, the profits alone from whose recovery conservatively estimated would pay off our entire present national debt within twenty-five years, it augurs well for the future that a joint meeting of engineers should choose as an appropriate subject for Oil and Gas Power Week that of "Coal Carbonization." For some unaccountable reason, engineers other than coal chemists have heretofore chosen to clothe the subject with a veil of impenetrable chemical mystery.

Yet a study of many years, both in Europe and America, convinces the speaker that the present relative slowness of this much needed development is, more than to any other one cause, due to lack of proper mechanical engineering ingenuity in retort design, and liaison between the engineer and the chemist. David Brownlie, of London, recently advised the speaker that in the preparation of his contemplated book on "Low-temperature Carbonization," he has discovered to date over one hundred and twenty processes and something like eight or nine hundred patents. Careful analysis of a thousand of these would probably indicate nine hundred of them right chemically and wrong mechanically, and eighty right mechanically and wrong chemically, with the balance perhaps of considerable technical promise.

Mechanically there is no more mystery to the retorting of coal than there is to the cooking of beef—in fact, except for the temperatures used, the processes bear striking similarity. You can grill it over a fire like a steak—either rare, medium, or well done. You can bake it in an oven. You can boil it over a fire and make soup of it. By so doing you can convert what originally appeared essentially a solid into three beneficiated components—a solid food in the form of steak or roast, a liquid food in the soup or gravy, and a gas which pervades the house to stimulate the

appetite! Similarly in carbonizing coal at low temperatures, we in general cook it "rare."[1] Thus we produce a beneficiated smokeless solid fuel—about 70 per cent.; liquid tar oils from twenty to thirty gallons per ton and from four to five thousand cubic feet of rich gas of from 750 to 950 B.T.U. per cubic foot. If we wished, we might even go so far as to drive off from the beef of our simile the fourth primary coal product—ammonium sulphate from which fertilizer is made.

NEED FOR BY-PRODUCTS.

With the gas industry just beginning to appreciate their industrial opportunities, and thus the use of gas increasing by leaps and bounds, the need for more and cheaper gas is apparent. When one considers that an equivalent enrichment of blue water gas, which now with gas oil costs some twenty cents per thousand feet, can be obtained with low-temperature gas for ten cents and still pay over half the average delivered cost of the original coal from which it is made, one begins to appreciate the intriguing possibilities of the method.

To many the need for the oils from coal is unfortunately not so apparent. If the nations of Western Europe—England, Germany, France, Italy—were known to have no present nor possible future domestic supplies of automobiles—if supplies elsewhere were relatively inaccessible and of decidedly doubtful quantity—and the U. S. Department of Commerce should announce that a comprehensive study of many years by competent engineers had revealed that our own supply was limited except at enormously increased costs to less than twenty years—one might expect an immediate stimulation of interest and research in aeronautics and other substitute transportation methods of promise. With such a natural monopoly, prices would shortly skyrocket. Even an economy régime at Washington might be expected to give the situation their prayerful consideration.

Yet, except that the announcement originates from another Government Bureau, such is the situation confronting the fuel on which present-day automobiles depend. Has interest or research been startingly stimulated? The British Department of Scientific and Industrial Research and our own Bureau of

[1] True low-temperature processes carbonize at from 450° to 650° C. The Everard Davies processes carbonize at from 700° to 800° C. High-temperature processes carbonize at from 950° to 1200° C.

Mines have received insignificant appropriations. A Coal Operators' Association in Germany contributes continuously and intelligently insofar as is consistent with its limited means. Several coal, oil, automotive and utility operators, and equipment manufacturers have contributed their bit. Generally, the industry remains unmoved. As with the natural gas industry of but a few years ago, oil users shrug their shoulders and say, "Don't worry, we'll get along somehow." Natural gas was wasted just as we are to-day wasting our by-product resources. The gas industry did indeed "get along somehow," but at the expense of a product many times its former cost.

Why this indifference to such a pressing national and world need? Mr. Henry L. Doherty, a large fuel user, as well as oil operator, before the American Gas Association last summer, said:

"As to our future oil supply, the situation is truly alarming. A committee of directors of the American Petroleum Institute started out with the avowed intention of proving that we had an ample supply of natural petroleum oil. They have published their report in a book of more than two hundred and fifty pages. While the casual reader may get the impression from this report that we have an adequate supply of petroleum, a careful analysis will not convince any intelligent man that if war should come again, even within thirty-six months, we as a nation would be certain to have an adequate supply of available petroleum."

As for the European domestic oil supply, it is well known that the oil reserves during the war were on occasion dangerously low. European navies and merchant shipping were and are now almost entirely dependent upon overseas supplies of fuel oil. In 1920, for example, of the total world oil production of about 97 million tons, the United States produced 64.8 per cent. and Mexico 23.3 per cent. (a total of 88.1 per cent.). Dr. Julian D. Sears, of the U. S. Geological Survey, estimates [2] that if our consumption of oil could continue without increase at the 1923 rate of 700,000,000 barrels, we would entirely exhaust all known domestic reserves recoverable by present methods within eleven years. Whether or not the geologist's estimate of our total reserve proves too low, "the vital fact remains—our supply is not inexhaustible and when once extracted it is gone forever." [2]

[2] Sears, J. D., "Engineers and the American Petroleum Situation," *Mech. Eng.*, **47**, No. 1, Jan., 1925, p. 10.

What will actually happen, of course, is that domestic consumption will continue to increase as in the past and "the actual result of approaching exhaustion will be declining production and increasing dependence on other sources of petroleum" (with ever-increasing transportation or manufacturing costs necessarily added).

Just as there is no international standard for cooking beef, so there can never be a universal panacea for coal carbonization. Some will always prefer steaks and others soup. National needs based on national resources must dictate such preferences in coal by-producting. Lack of realization of this has caused many useless expenditures in attempts in the United States to apply, wholly or in part, methods devised in Europe to American conditions.

In Europe, the better grades of coal such as are now being mined in the United States have been worked out years ago. Most of the British, French and German mines are from two to three times the average depth of the American bituminous mines, resulting in much greater overhead pressures on the coal seams. This in turn produces much higher percentages of fine sizes in mining. For these reasons the majority of European bituminous coals are washed and sized. On the other hand, of the total American bituminous production, less than 5 per cent. at present is beneficiated. The problem, therefore, of disposition of fine sizes of bituminous in Europe is even more pressing than our well-known American problem of anthracite fines. Furthermore, the central heating system, in which fine coal can be burned if necessary for domestic service, has been relatively little adopted, particularly in England, the old open fire grate still being principally relied upon. Europe, therefore, is of necessity forced either to briquette or waste a large portion of her bituminous fines. This is not the case in America, and will probably not be for the present generation. Briquetting costs money, and as long as American bituminous operators can dispose of their slack for steam purposes at reasonably profitable prices, it will not pay to further classify and briquette it.

Correspondingly semi-coke briquettes are readily welcomed in large quantities at profitable prices by European domestic fuel users who know their merits, while their relative unfamiliarity in America makes sales resistance at preferential prices great. It

would seem therefore that the economic desirability in America of making such briquettes the major end-product as in many European processes would be subject to serious question. Few question the *technical* desirability of semi-coke briquettes as a means of smoke abatement, but the *profits* demanded by the financier seem more probable at least for the immediate future in the conversion of the semi-coke into electricity for which there is a universally profitable market.

In general it may be said that inasmuch as the quantity, quality and character of by-products may be widely varied with differing time and temperature cycles and retorting technique, it is obvious that for commercial success one must adapt the method to the national need. The reverse of this figuratively represents "carrying coals to Newcastle" and is hence foredoomed to failure.

LOW-TEMPERATURE CARBONIZATION.

Low-temperature distillation apparatus may be divided into two classes, the first heated externally, heat being transmitted from outside through a wall, the second heated internally, carbonization being directly effected by hot gases passing through

FIG. 1.

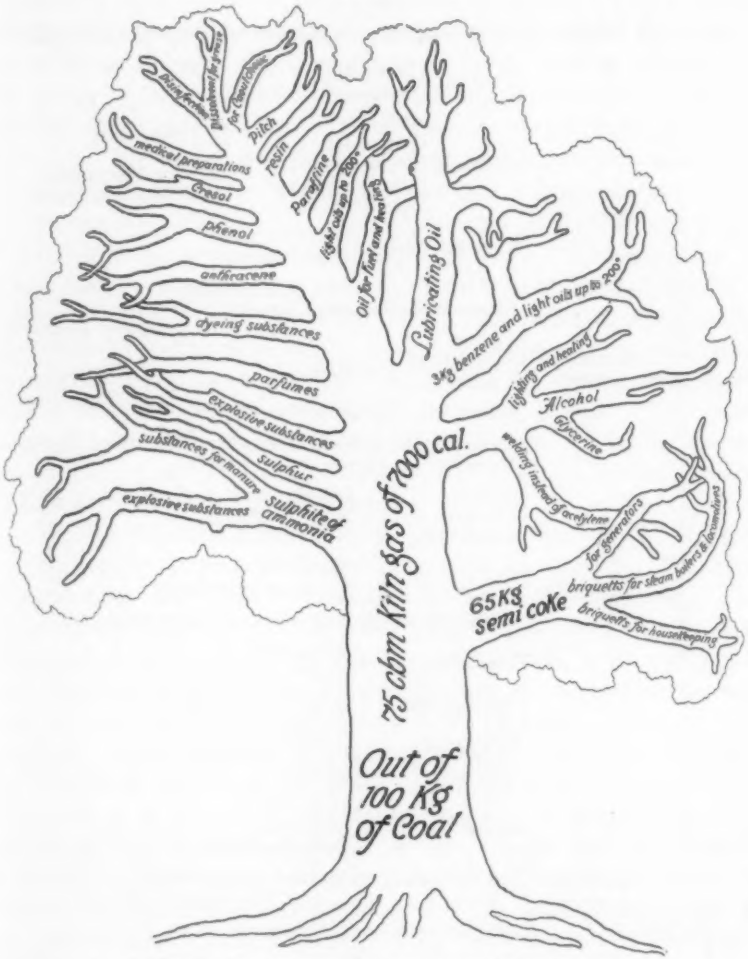
Yield per Ton of Coal Treated.	High-temperature Carbonization.	Low-temperature Carbonization.	
	By-product Coke Oven.	Externally Heated Retorts.	Internally Heated Retorts.
Coke, per cent.	60–70	70–80	60–75
Volatile matter in coke, per cent.	1–2	7–15	7–15
Gas, cu. ft.	11,000–12,000	3,000–5,000	20,000–50,000
Calorific value of gas, B.t.u. per cu. ft.	520–550	800–1,000	150–250
Tar, gal.	10–12	20–28	18–20
Specific gravity of tar.	1.19	1.07–1.09	1.02–1.07
Light oil for motor fuel, gal.	2.5–3.0	2.5–3.0	None
Ammonium sulphate, lb.	25–30	10–12	12–18

the charge. Fig. 1 [3] shows comparative yields of these two methods and their relation to high-temperature yields. The apparatus for external heating may be further sub-divided into stationary and rotary furnaces. The stationary furnaces may be of the shaft type, the horizontal type, or of the tunnel kiln type.

[3] Numerous slides shown are furnished by courtesy of Mr. A. C. Fieldner, Superintendent, U. S. Bureau of Mines, Pittsburgh, Penna., the writer's associate during a study of this subject in Europe.

Fig. 2 shows in somewhat greater detail the yields from the Thyssen rotary, and their uses as given the speaker by their former chief engineer. Fig. 3 shows a similar chart by an

FIG. 2.



Distillation of coal in rotary kiln, products gained and their use.

American investigator,[4] which differs principally from the German by the omission of anthracene, explosives, dyestuffs and

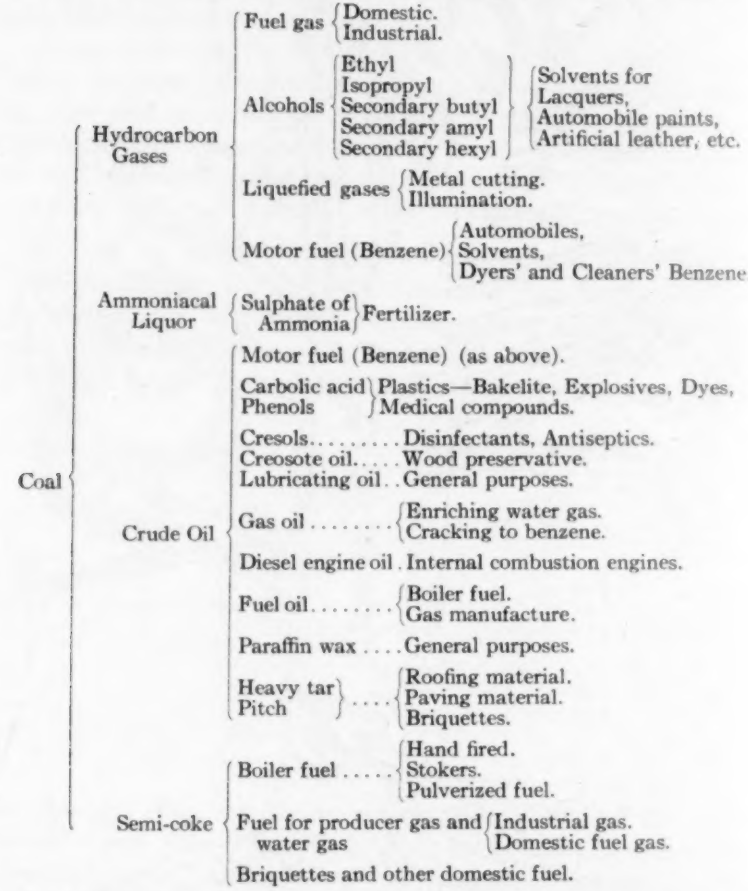
[4] K. M. SIMPSON, Consulting Engineer, New York City, N. Y.

perfumes (which apparently have greater interest to date to German chemists than they have to our own).

I. *Vertical Retorts.*—If the production of low-boiling benzene and gas is aimed at, the volatile of the coal is best distilled

FIG. 3.

Principal Products of Low-temperature Distillation of Coal and Their Uses.



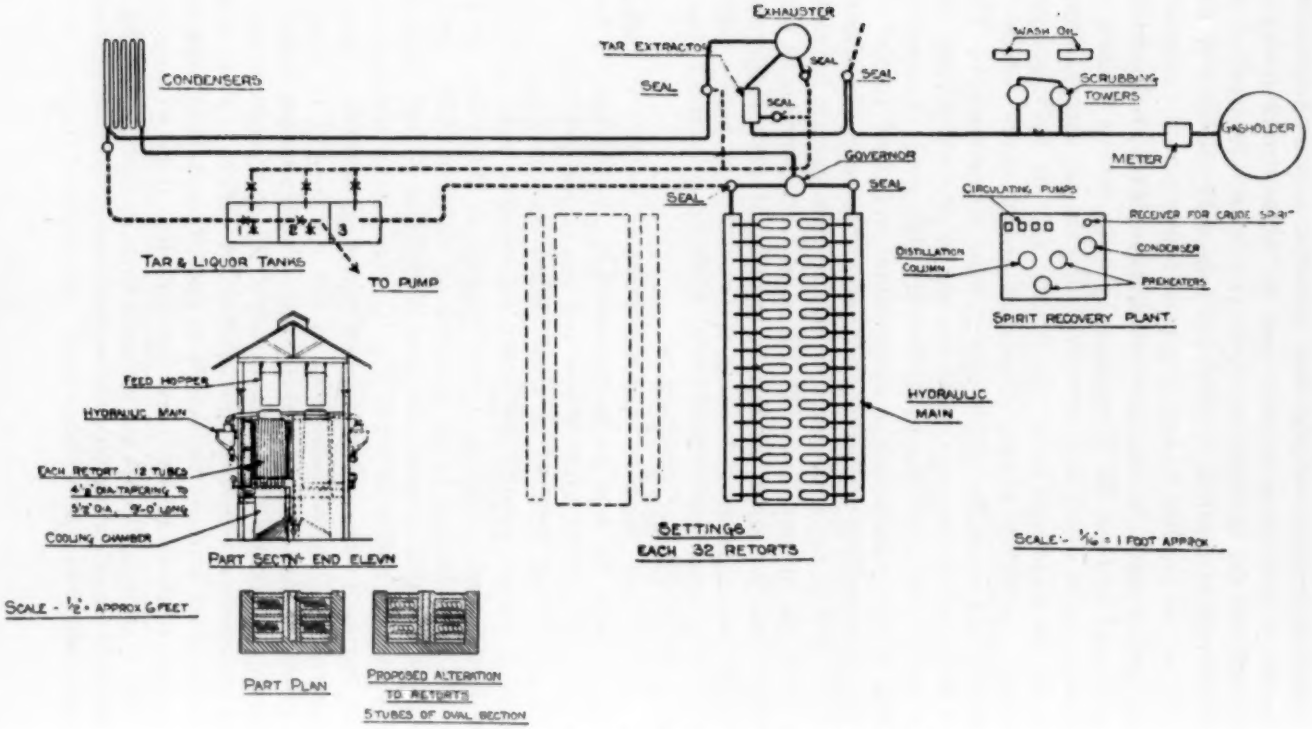
by applying external heating. The relatively low temperatures of 400° to 500° C. required for this purpose admit of the use of retorts of steel or cast iron, which are preferable to most refractory materials on account of their impermeability to gas and greater thermal conductivity. Stationary retorts offer the advan-

tage over rotary furnaces that they do not require a power drive. The rate of distillation depends upon the thermal conductivity of the walls and the thickness of the layer of coal. In view of the low thermal conductivity of coal and semi-coke the layer should be as thin as possible to keep the carbonizing period reasonably short and provide for an economical throughput of the retort. An attempt to raise the throughput by more intense heating of the retort walls would lead to superheating the tar vapors, diminish the tar yield and lower the quality, *i.e.*, its hydrogen percentage. In other words, a product would result which in quantity and character would approximate coke-oven tar. This is a defect of all processes which profess to produce primary tar, but claim at the same time to realize very high yields of ammonia. These become possible only at temperatures from 600° to 800° C., while in normal low-temperature tar production most of the nitrogen remains in the semi-coke. It may be subsequently recovered as ammonia by gasification of the semi-coke much more completely than would be possible by applying higher carbonizing temperatures. To avoid hanging up the charge of highly caking or swelling coals and difficulties in discharging, vertical retorts are generally given a suitable taper.

The British "Coalite" process, invented by Mr. T. Parker, was probably the first to be commercially applied for the low-temperature carbonization of coal and was on this principle. The first patent was granted in 1890 (thirty-six years ago[5]), but principal process patents were taken out in 1906, 1907 and 1908. An installation consisting of two batteries of thirty-two vertical retorts, each battery being designed to carbonize fifty tons of coal per twenty-four hours, has been installed at Barugh, Barnsley in Yorkshire, and is shown in Fig. 4. Each retort consists of an iron casting in one piece, containing twelve vertical tubes tapering from 4½ in. internal diameter at the top to 5½ in. internal diameter at the bottom, and 9 ft. long. The retorts are heated by burning a mixture of low-temperature gas and producer gas in the combustion chamber surrounding the retorts. Four hours are required to coke the charge at 650° C. It is claimed that in this retort which has been evolved after trials of numerous

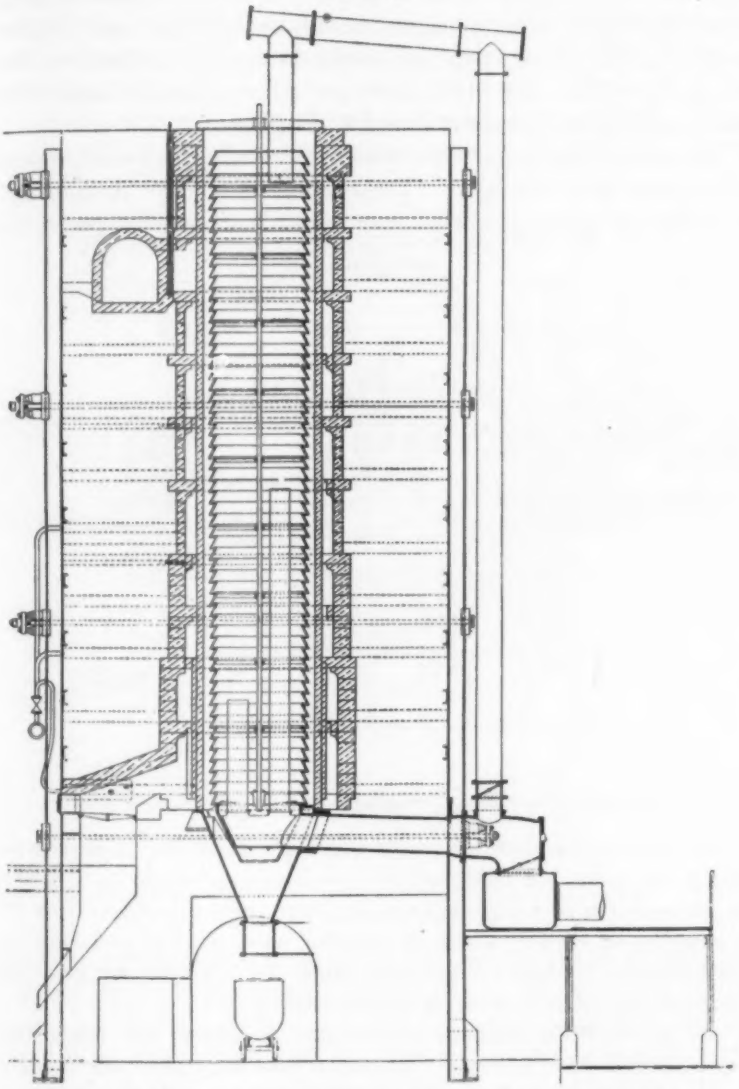
[5] It is interesting to note that in Central Germany low-temperature carbonization of brown coal has been a commercial success for about fifty years, so it is not entirely a new thing.

FIG. 4.



Parker " Coalite " process as installed at Barugh, Barnsley in Yorkshire.

FIG. 5.



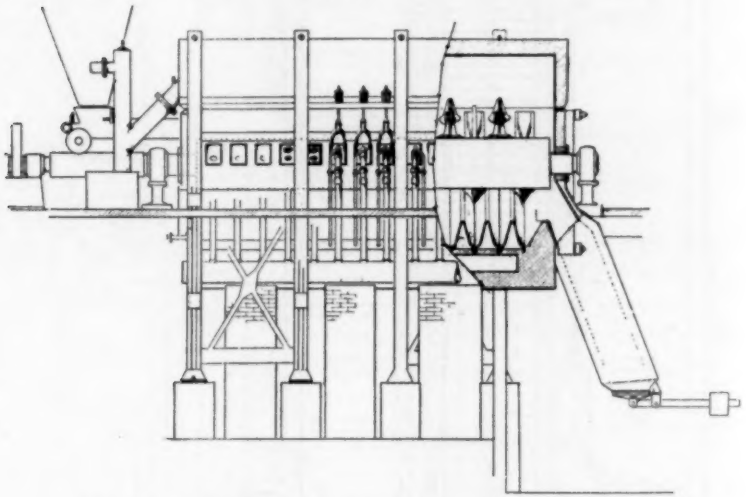
Rolle vertical retort for low-temperature carbonization of German brown coal.

other designs, that a special cast iron is used that will not grow or distort at the temperature of carbonization. Swelling and non-swelling coals are blended in the charge so that the resultant

coke contracts sufficiently to be discharged easily. There is some question whether after a lengthy period of operation such retorts would not distort or warp sufficiently to make it difficult to discharge the coke. Extensive tests on this installation have been made by the Fuel Research Board in England.

Retorts of this type for the treatment of brown coal and oil shales have long been used. These materials present no difficulty in caking or swelling, and if they are rich in tar, the properties

Fig. 6.



McIntire horizontal retort in commercial operation at Fairmont, W. Va.

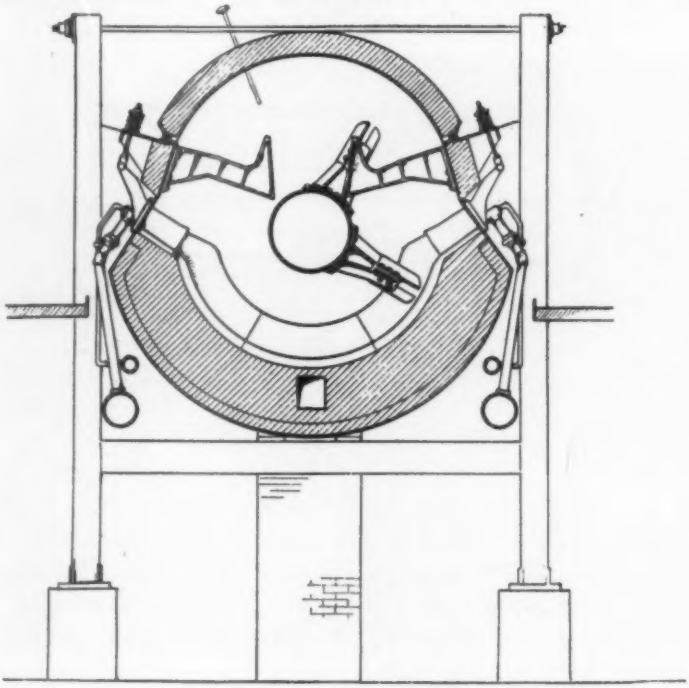
of the solid residue are of no consequence as in the case of coal. The plants were not designed for producing primary tar. There was no interest in undecomposed bitumen, and the object was the production of well-crystallized paraffin wax, gas oil and fuel oil. Even the production of benzene from the carbonizing gas was not a decisive factor in these older processes.

In the Central German carbonizing industry, the Rolle furnace, another vertical retort, has been used for many years. It is shown in Fig. 5. It is intended for the processing of raw brown coal, which, air-dried by suitable storage, admits of continuous working. The height of these retorts is about 33 feet. The retort is built of fire brick and is surrounded by flues. The coal slides down between the walls of the retort and an inner

cylindrical body, built up Venetian-blind fashion, of a series of bells resting upon one another through which the gases and vapors find an outlet. Large numbers of such retorts have been in operation for many years in Central Germany.

Horizontal Retorts.—Of the externally heated retorts of the horizontal type probably the most interesting in America is the

FIG. 7.

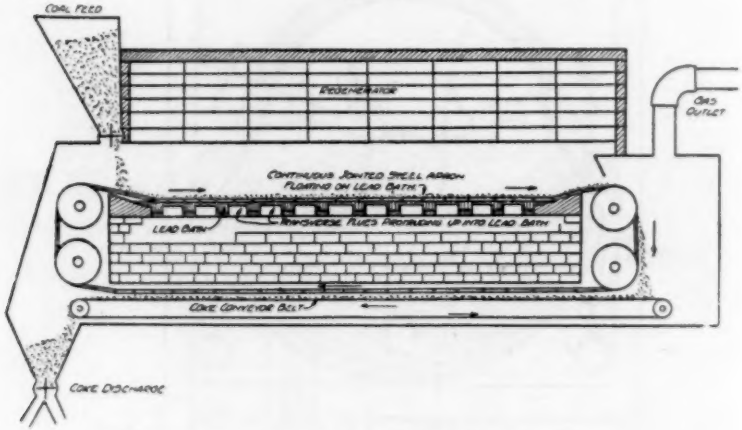


End elevation of McIntire retort.

McIntire retort shown in Fig. 6. The coal is fed in the one end and the semi-coke discharged at the other. As shown in Fig. 7, a series of paddles carried on a central rotating shaft moves coal along the bottom of the retort, agitating it at the same time. The heating is done along the bottom surface over which the coal is being conducted and the resulting coke is discharged in small pieces due to the agitation. This fine coke can be briquetted with a pitch binder, recarbonized and used as a domestic or producer fuel, or screened out and fired in pulverized fuel furnaces. A

retort of this design has been in operation two years. During the first year, it treated 11,500 tons of coal from which was recovered 350,000 gallons of oil—a truly remarkable performance, when one considers that the usual problems incident to the starting and tuning up of all new mechanical equipment were solved during this period. Since August, 1925, the operation has continued its satisfactory rate, turning out throughout the entire anthracite strike 1100 to 1200 tons of briquettes each month from 1300 to

FIG. 8.



Piron tunnel kiln type retort as installed by Ford Motor Company.

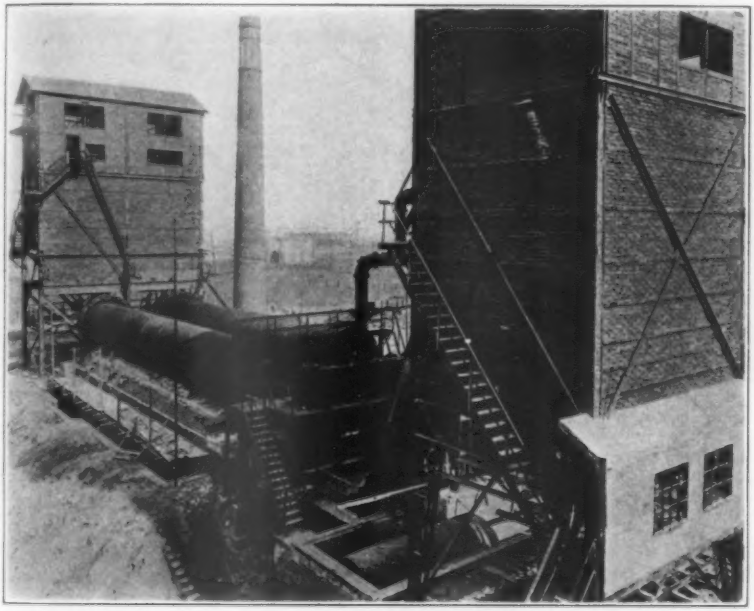
1400 tons of coal. A maximum capacity of nearly seventy tons per day has been established and a safe normal capacity of fifty tons is easily maintained. Including necessary inspection and cleaning periods, the average commercial throughput per day on an annual basis is 40–45 tons.

Tunnel Kiln Type Retort.—Representative of the tunnel kiln type retort are the well-known Ford installations of the Piron retort, one of which is shown in Fig. 8. In this instance, the coal is conveyed through a closed retort on an iron conveyor which floats across the surface of a molten lead bath. The heat of the lead devolatilizes the coal and the coke is carried out and discharged from the conveyor belt. It is claimed that a layer of coal one-half inch thick is completely carbonized in five minutes at a temperature of 650° C. The fire brick retort is about 50 ft. long. Gas is the source of heat for maintaining the molten lead bath at the required temperatures. The products of combustion

pass through narrow passages under the bath into chequer brick-work regenerator settings overhead. The semi-coke delivered is not in a form suitable for use as a domestic fuel, it being the intention to pulverize the greater portion of it for steam-raising purposes.

Rotary Retorts.—Rotary retorts have found special favor in Germany and to some extent England. The first rotary retorts of

FIG. 9.



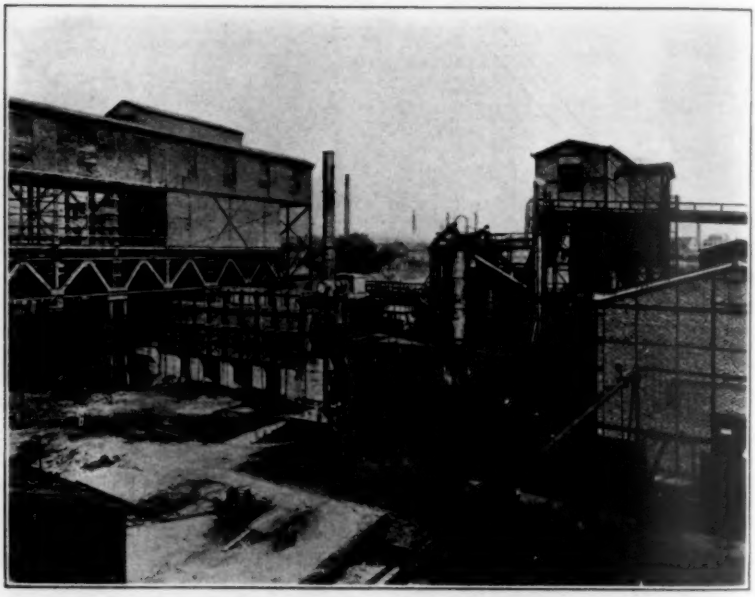
Thyssen rotary retort at Prince Bismarck Colliery.

really large dimensions were designed by Thyssen and Company, at Mulheim am Ruhr, a few years ago. At present there is a plant of 100 tons per day throughput at Thyssen and Company's works, another at the Hamburg Gas Works, and two units at the Prince Bismarck Colliery which are shown in Figs. 9 and 10. (Fig. 11 shows the installation at Mulheim am Ruhr.)

The Thyssen retorts are of surprising simplicity and capacity. The iron drums are built in one piece 78½ ft. long by 8½ ft. in diameter. The coal is fed into the rotating tube at one end and is carried through the length of the tube in two hours by

means of helical screw lifters riveted to the drum, dropping out at the other end in the form of semi-coke. The iron drum runs in a chamber which is fired with producer gas, the chamber being heavily lagged against heat losses. The distillation gases leave the drum together with the tar vapors at the same end as the semi-coke. The principal difficulty with which the Thyssen plant has to contend is the formation of dust. This trouble is particularly

FIG. 10.



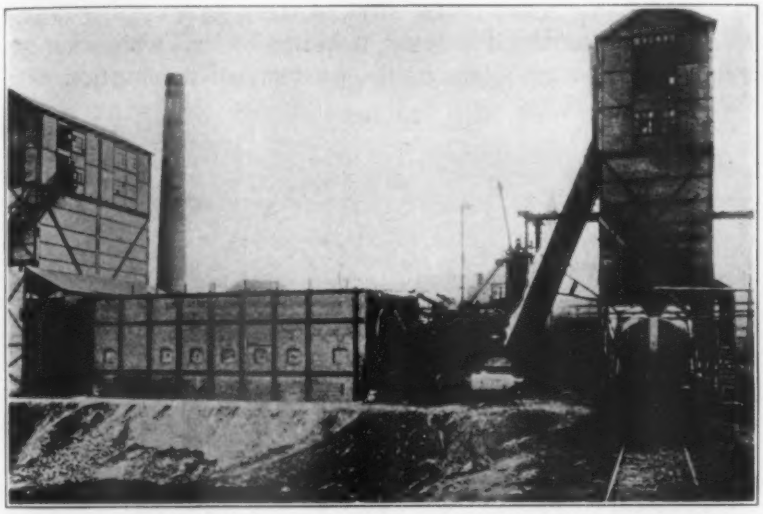
Another view of Thyssen rotaries at Prince Bismarck Colliery.

pronounced in large rotary retorts because the friable semi-coke is kept in rolling and tumbling motion and the dust thus continuously stirred up. As the presence of dust in the tar interferes with the separation of the water and lowers the value generally, it is necessary to remove it before the tar is condensed. Special dust separators are thus required to throw down the dust from the hot gases. Even with such collecting equipment, the tar is likely to contain 1 to 2 per cent. of dust, which seriously detracts from the commercial value of the low-temperature pitch. The retort at Mulheim, said to have been operating continuously for a

period of five months, showed no signs of warping or bends in the long rotary shell.

In England, the most interesting rotary retort is the Fusion

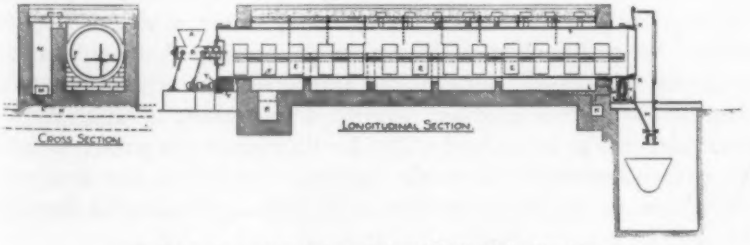
FIG. 11.



Thyssen rotaries at Thyssen and Company plant, Mulheim am Ruhr.

retort which is being offered by Vickers, Limited, and is shown on Fig. 12. The material to be treated enters the rotary retort through an automatic feed valve, passes through the retort tube

FIG. 12.

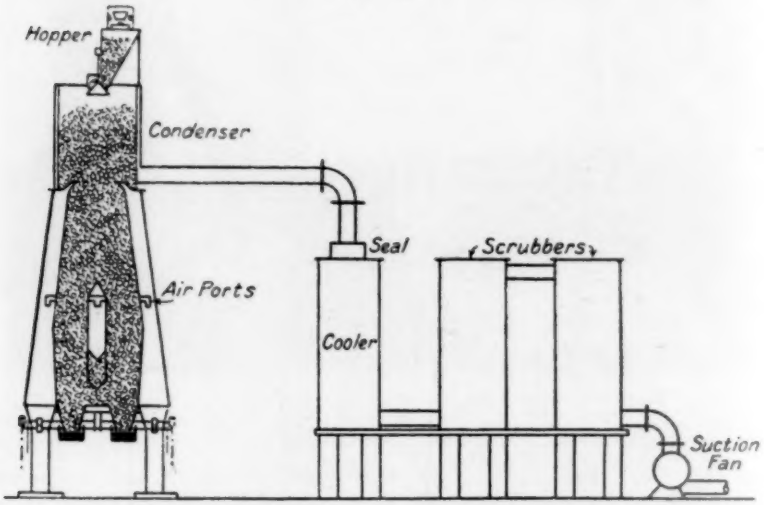


Fusion rotary retort as installed at Middlewich, Cheshire.

where it becomes heated, and is discharged at the other end through an automatic valve to a receptacle. To prevent sticking of the material on the inside of the retort, a star-shaped breaker

is employed. This consists essentially of steel plates radiating from a central spider which extends from end to end in the retort, the entire breaker being free to tumble over as the retort rotates. These breakers are said not only to stir the coal and expose fresh surfaces to the hot walls of the retort, but also to give a hammering and chipping action on the sides of the retort, keeping it free from caked material. The retort is heated by the combustion gas from a producer gas plant or the products of combustion of a

Fig. 13.



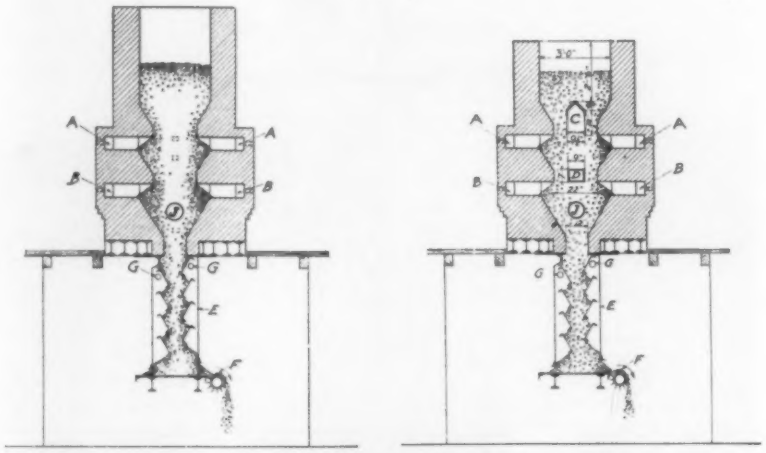
Maclaurin internally heated vertical retort as installed at Glasgow.

hand-fired or mechanically operated furnace. The products of combustion pass into the combustion chamber which is located on one side of the retort. They enter the heating chamber through a number of ports properly placed and capable of regulation at the chamber in such a manner that the temperature at any part of the retort can be controlled. The heating gases are passed around the rotary retort and leave the heating chamber at the feed end. They flow in opposite direction to the flow of material through the retort.

II. *Internal Heating.*—In general four heating media have been attempted in internally heated retorts—superheated steam, hot producer gas, hot coke-oven gas and hot flue gases. There is little doubt that steam is the most suitable direct heat carrier

because it can be separated from the products of distillation by suitable cooling, so that these products are obtained in an undiluted form. Such a process, however, gives little commercial promise and the operation is very expensive for complete tar recovery. It is not sufficient merely to cool the large amount of steam necessary to 212° F.; the steam must be condensed to water to make the extraction of benzene possible. This involves further steam raising, a combination which even with good heat

FIG. 14.



Cross-section of Hood-Odell carbonizer for American lignites.

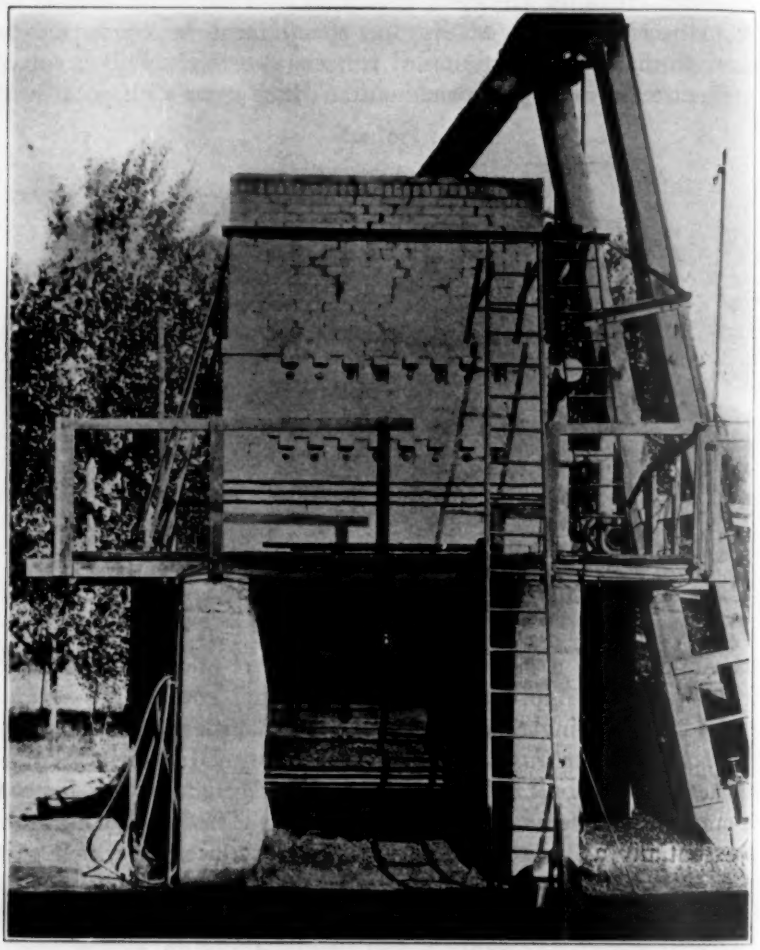
exchange means a large expenditure of fuel and cooling water. Owing to their improbability of commercial success the several methods employing this principle will not be described.[6]

Hot Producer Gas as a Heating Medium.—Maclaurin in Scotland effects carbonization by means of hot generator gas instead of superheated steam, as shown in Fig. 13. The Maclaurin retort is essentially a by-product recovery gas producer in which part of the semi-coke is burned to producer gas, the sensible heat of which carbonizes the descending charge of coal. The experimental producer at Grangemouth, Scotland, is of square cross-section, about 45 ft. high by 8 ft. wide at the widest part. The air-blast is introduced about 12 ft. above the discharging doors,

[6] Please note this does not refer to the steaming of retorts, which is, in the speaker's opinion, very desirable. It applies only to the use of steam as the sole medium for carrying heat for carbonizing.

through a large number of narrow ports in opposite side walls, and also by similar ports in a dividing wall which is carried across the centre of the retort at the same level. The coke is

FIG. 15.

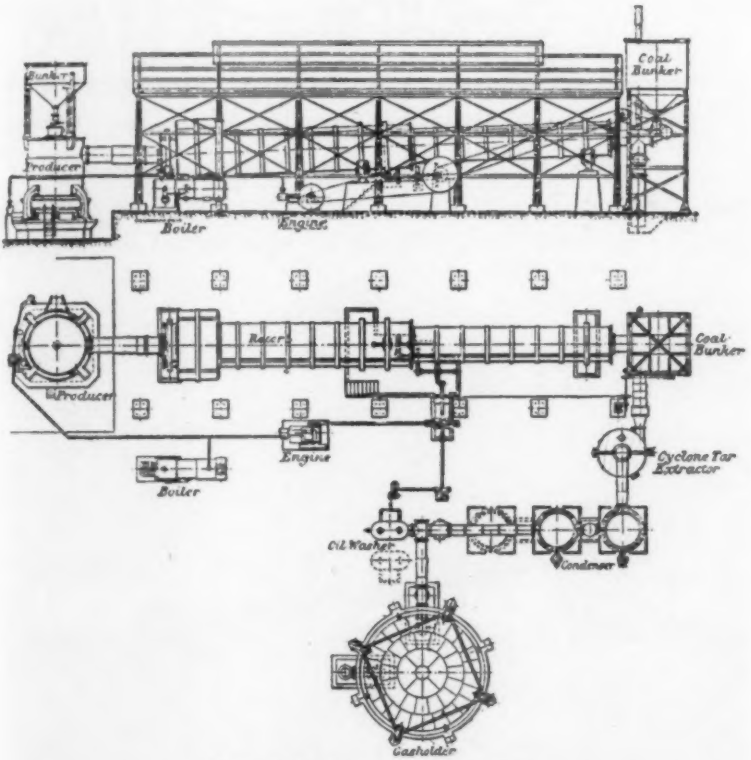


Experimental installation of Hood-Odell lignite carbonizer.

cooled in the zone below the air port, steam being injected at the discharge doors. A part of this steam ascending through the coke becomes heated and partly decomposed into water gas, thence passing upward and mixing with the producer gas formed in the

combustion zone. The raw coal is discharged from an elevated hopper through a bell into the top of a cylindrical steel tank 8 ft. in diameter by 10 ft. high, resting on the brick work at the top of the retort. This tank serves as a condenser for the oils and tars which drain down the side of an inner steel cylinder which dips into the well formed by a dished flange at the bottom of the

FIG. 16.

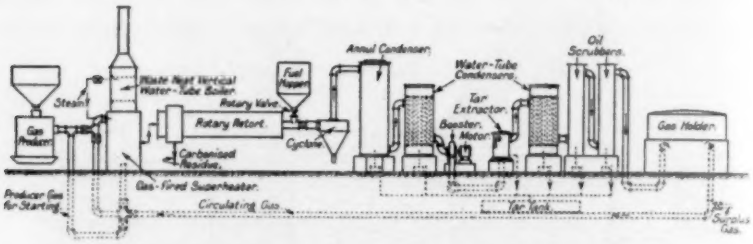


Nielsen inclined rotary internal heating.

tank. From the annular space between the tank and the cylinder, the gases are led off to tower coolers and scrubbers. The plant is continuous in operation and a retort of the dimensions given contains about thirty tons of coal. It may be run either for complete gasification or for production of smokeless fuel, the only adjustment necessary in changing over consisting of the regulation of the air-blast and gas outlet valves. A 100-ton plant

employing this process has recently been installed at the Dalmarnock Gas Works at Glasgow, Scotland, and is being watched with great interest. The Maclaurin carbonizer is quite similar to the

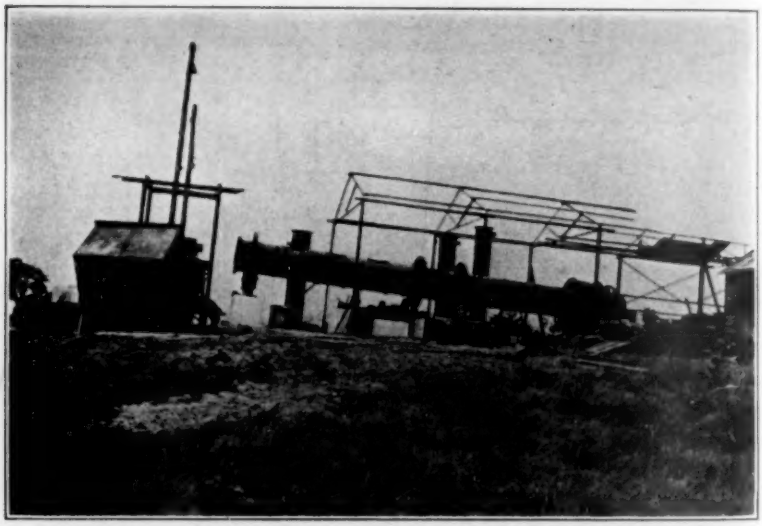
FIG. 17.



Superheated circulating gas system of Nielsen ("sensible heat") process.

Hood-Odell lignite carbonizer which has been the most promising method yet tried on brown lignite in America. A cross-section

FIG. 18.



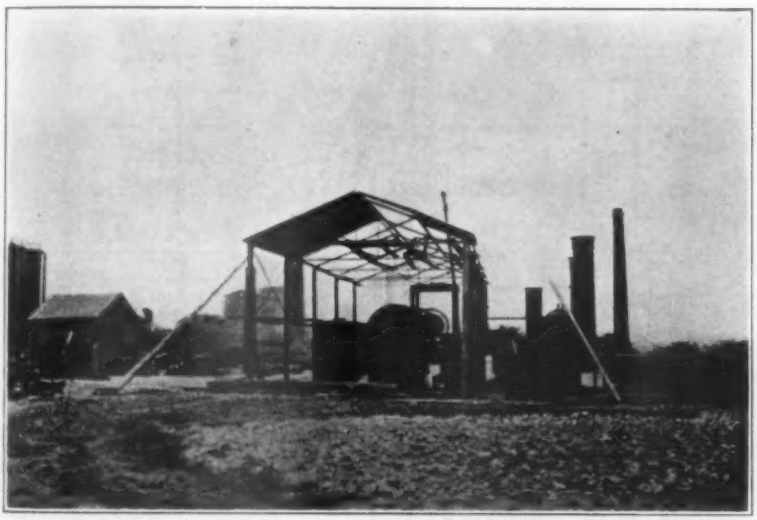
Nielsen internally heated rotary as installed at Silkstone, Yorkshire.

of a retort of this type is shown in Fig. 14. An experimental installation is shown in Fig. 15.

The big advantage of these types is that the heat is generated within the carbonizer and transferred without loss by a gaseous

medium to the surface of each particle of fuel. It has no moving parts to get out of order and is constructed of standard refractory materials that have stood the test of experience in gas works and coke-oven practice. The first cost is relatively low and the output per unit is higher than most low-temperature processes. The disadvantage is that the semi-coke is small, bulky, and somewhat friable. Although smokeless, it is not likely to be popular for domestic use for these reasons. The large amount of low-calorific

FIG. 19.



End view of Nielsen rotary at Silkstone, Yorkshire.

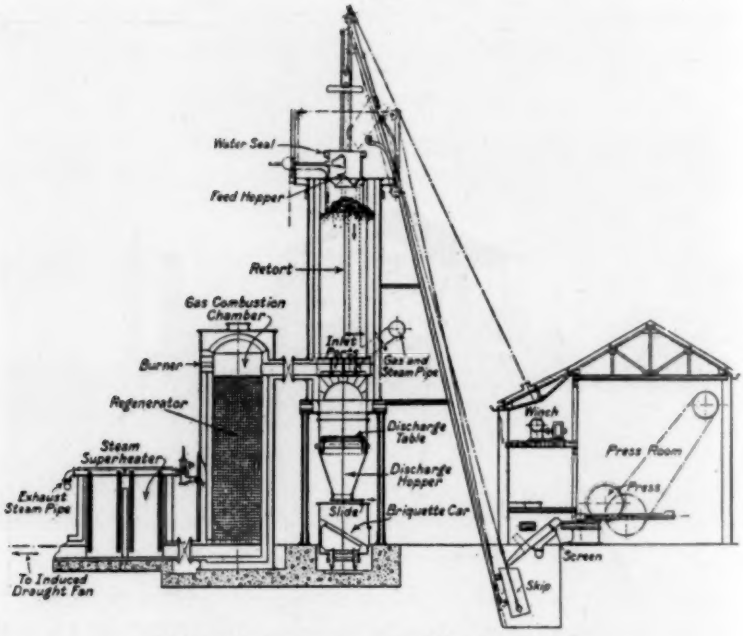
value gas produced limits the use of the Maclaurin producer to such places where the gas may be utilized without transport, such as gas works, glass or ceramic works, or metallurgical plants.

The Nielsen retort shown in Fig. 16 also makes use of the sensible heat of producer gas for the carbonization of coal. His process differs from Maclaurin's in the fact that he employs the rotary inclined retort as shown on Fig. 17. The next two figures (18 and 19) show two views of the Nielsen carbonization plant erected at Silkstone, Yorkshire, England. The hot gas from the producer is passed by a short connection into the discharge end of an inclined rotary retort. Coal is fed into the upper end travelling toward the other end over a system of baffles designed to secure

intimate contact of the hot producer gas that enters at the lower end of the retort with all parts of the coal charge. This process was originally designed for installation at steel plants to recover and utilize the sensible heat of producer gas for low-temperature distillation, using the resultant semi-coke as a gas producer fuel. The long rotary is lined with fire brick and a steel shell is inserted on the outside to reduce heat losses to a minimum.

Hot Coke-oven Gas as a Heating Medium.—Sutcliffe and

FIG. 20.

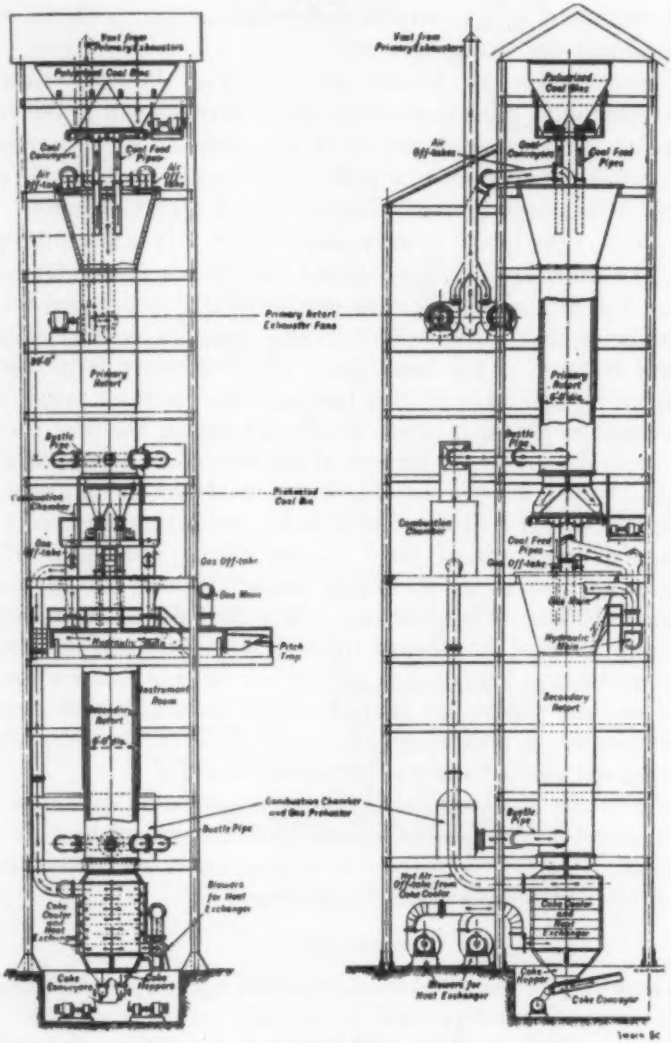


Sutcliffe and Evans " pure coal briquette " process.

Evans have conducted researches into the problem of low-temperature carbonization, with the object of obtaining a smokeless fuel. By mixing coal rich in gas with lean or oxidized coal they propose to improve the physical structure of coke, the various coals being ground and briquetted at high pressure without the addition of a binder. Their briquettes are described as being sufficiently hard and strong for carbonization in high vertical retorts. Provided that a high enough compressive strength of the briquettes can be obtained, these inventors consider retorts

with a daily throughput of 1000 tons possible. As shown in Fig. 20, they propose to effect the low-temperature carbonization

FIG. 21.



McEwan-Runge vertical internally heated retort for carbonization of pulverized coal as installed at Milwaukee.

of their compressed fuel by forcing hot coal gas through a perforated cylinder, axially mounted in the vertical retort so that it takes

up the products of carbonization. The gas is continually reheated in two regenerators, one of which is giving up its heat to the return gas, while the other is brought up to temperature again by the combustion of the surplus carbonization gas, with the usual arrangement for changing over.

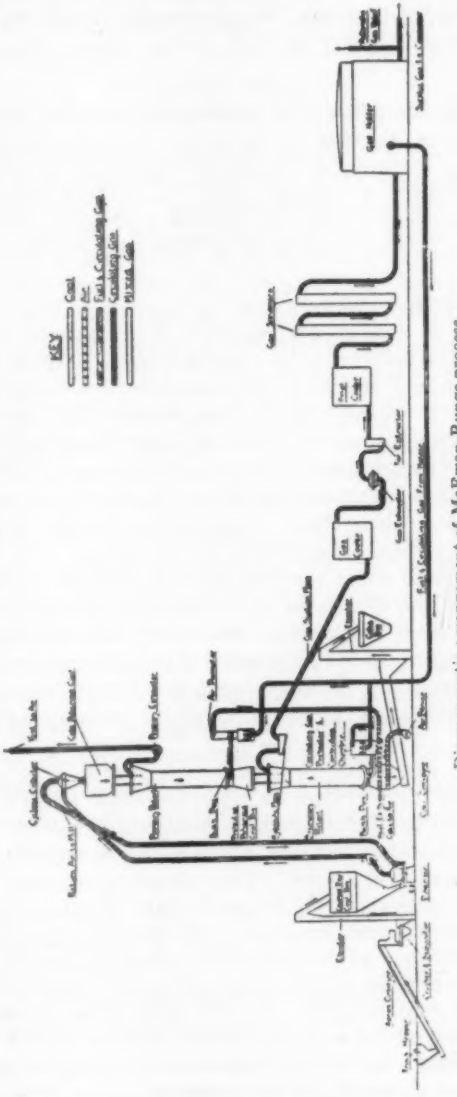
Carbonization by Means of Flue (or Re-run) Gases.—Undoubtedly the most interesting recent development to American operators is the announcement of the installation of a 200-ton McEwan-Runge commercial scale experimental retort at the plant of the Milwaukee Electric Railway and Light Company. The operation of this plant is shown in Fig. 21. It utilizes the principle of carbonization of pulverized coal in suspension by means of flue (or re-run) gases. The powdered coal is dropped into an internally heated tower where it will come in contact with an upward current of hot inert gas. The extremely large surface presented by the finely divided fuel particles insures a rapid transfer of heat so that distillation is effected during the time the fuel falls from the top to the bottom of the tower, a distance of about 30 ft. When using coals having a tendency to agglomerate, advantage is taken of the fact that by preheating the coal to an average temperature of 365° C. the coking tendencies of the particles are destroyed. It is then passed through another tower, immediately beneath the first one, where the balance of the volatile matter is distilled by passage through a counter-current flow of gas at an average temperature of 565° C. Fig. 22 shows how the gases and oil vapors are carried off to scrubbing and cleaning apparatus and the pulverized semi-coke conveyed from the bottom to be burned under boilers in pulverized form.

The choice as examples of the processes described should not be construed as the speaker's particular recommendation of such processes. They serve merely as typical examples of the classes into which past efforts divide themselves.

CONCLUSION.

There is no royal road to commercial success in the exploitation of any technical process in its early stages, no matter how much a boon it may subsequently prove to humanity. It has been estimated that of new enterprises, only one in seven achieves success. Watt's steam engine—perhaps the greatest engineering invention of all—rendered bankrupt one concern and very nearly

FIG. 22.



Diagrammatic arrangement of McEwan-Runge process.

a second before it became a paying proposition. The great Bouillaud insisted that the telephone was only a ventriloquist's hoax. In 1827 a learned Frenchman insisted that it was folly to think that water could be led to the upper floors of a house by pipes.

In closing, therefore, the speaker regrets that he cannot offer a guaranteed formula for present-day commercial success in coal by-producting. He feels sincerely, however, that we are rapidly nearing the "Age of Coal Processing," and that with its inception industry will enjoy new and undreamed of profits.

Rangefinders.—Rangefinders as known to-day consist of two main types, each type depending upon the measurement of the parallax at the target subtended by a known base. The first type consists of two independent instruments, separated by a considerable distance and known as a "Long Base" rangefinder; the other type has the base length contained within a single instrument and is known as a "Short Base" rangefinder. In general the base is horizontal, though in certain localities a vertical base can be used with advantage. The actual number of long base rangefinders in use is not great; the number of short base rangefinders is very great.

The attempt to solve rangefinding problems is at least a hundred years old; but the invention of a special instrument containing the base in itself dates from 1860, when Mr. Patrick Adie, of London, patented a rangefinder of this type. Lord Kelvin and Mr. James R. Napier considered the problem, and Sir W. Christie, late Astronomer Royal, and Mr. H. R. A. Mallock both designed short base rangefinders.

No really successful instrument, however, was produced until Professors Barr and Stroud, in reply to public advertisements by the War Office and by the Admiralty, designed between 1888 and 1892 a rangefinder for each Service which was successful and which fulfilled the desired conditions. The rangefinders they designed and made were 30 inches and 60 inches in base length. The two original instruments constructed were on exhibition during the Optical Convention recently held at the Imperial College of Science, London.

The advance made in the construction of rangefinders is seen by comparing the requirements of 1888 with those of the present day. In 1888 the instrument was desired to work at 1000 yards within an error of 40 yards: To-day the requirement is for rangefinders which measure ranges of 40,000 yards, within an error of 100 yards at that range, equivalent to 3 inches at 1000 yards. The "Short Base" rangefinders are now constructed with base lengths varying from 1½ feet to 100 feet.

INDUCTANCE OF OVERHEAD TRANSMISSION LINES WITH UNEQUAL SPACING OF WIRES.*

BY

ALFRED STILL.

Professor of Electrical Design, Purdue University, LaFayette, Ind.

THE current in any one conductor of an electric transmission line, whether the system be single-phase or polyphase, may be considered as the sum of a number of component currents which are exactly equal, but opposite in direction, to the currents in the remaining conductors. The induced e.m.f. in any one conductor of an alternating-current transmission may therefore be considered as due to a resultant magnetic flux which is the summation of the component fluxes in the two or more single-phase circuits formed by one particular conductor and each of the other (parallel) conductors. This method of calculating the inductance of transmission lines with any arrangement of parallel conductors was the basis of articles contributed by the writer to the *Electrical World* and published in the issues of May 23, 1908, and September 15, 1910. The same method may be used for calculating the induced voltage in a three-wire, three-phase transmission when the wires are not equidistant, but are regularly transposed so that the total reactive drop is the same in all the wires. It is well known that the equivalent equidistant spacing on a three-phase transmission with any arrangement of conductors is the geometric mean of the actual distances between wires, but the writer believes the following proof of this relation to be shorter than the one usually given.

The magnetic flux surrounding a straight wire of circular cross-section, up to a distance d cm. from the centre of the wire, is

$$\Phi = 0.2lI \log_e \frac{d}{r} \text{ maxwells.} \qquad (1)$$

Where l = length of conductor, in centimetres,
I = current, in amperes,
r = radius of cross-section of wire, in centimetres.

This formula assumes the permeability of the medium surrounding the wire to be unity ($\mu = 1$), and it therefore applies to a single wire of any system of overhead electric power transmission. The formula does not take account of the flux of induction inside the

* Communicated by the Author.

conductor. If it is desired to calculate the self-induced e.m.f. when the current is alternating with a frequency of f cycles per second and the separation between outgoing and return wires is d centimetres, we may use the following formula which includes the relative drop due to the flux in the material of the (non-magnetic) conductor.

$$\text{Reactive volts per mile of single conductor } (IX) = aI \log_e \frac{d}{r} + bI \qquad (2)$$

where $a = 0.00466f$ and $b = 0.000506f$.

The development of these, or equivalent, formulas is given in nearly all books treating of overhead transmission lines.

Since, as previously stated, any one wire of a power transmission line may be thought of as carrying the outgoing current, the return current—equal in amount, but opposite in direction—being carried by the one or more remaining conductors, it follows that, if all of the current I returns at a distance d from the centre of the outgoing conductor, the formula (2) may be used for calculating the total IX voltage drop in the single wire. This formula is therefore applicable to a two-wire, single-phase transmission and also to a three-phase transmission with the three conductors occupying the vertices of an equilateral triangle. But it is not applicable to a single-phase system in which the return current is divided between two or more conductors situated at different distances from the outgoing wire, or to a three-wire, three-phase transmission in which the wires do not occupy the vertices of an equilateral triangle.

In Fig. 1, the total outgoing current I is supposed to be the current in one of the several parallel conductors, while the total return current is divided between all the remaining conductors of the transmission line, the condition being that

$$\dot{I} = -(\dot{I}_1 + \dot{I}_2 + \dot{I}_3 \cdots + \dot{I}_n).$$

Let d_1, d_2, d_3, etc., be the distances between the centres of the several conductors carrying the return current and the conductor carrying the outgoing current, and note that the total flux surrounding the latter conductor may be considered as the sum of the component fluxes, namely, the flux due to a current $-I_1$ returning at a distance d_1; the flux due to a current $-I_2$ returning at a distance d_2, and so on, for any number of components of the total current I. Each of these separate components of the total

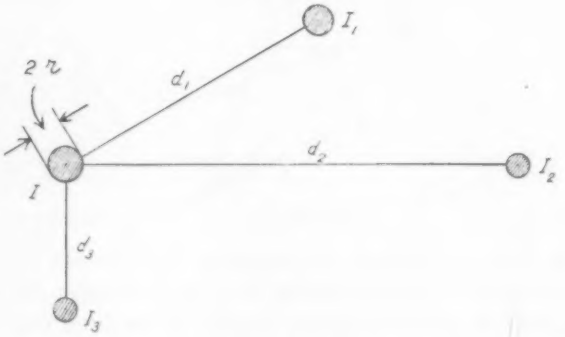
flux can readily be calculated by means of formula (1), and the expression for the total flux surrounding a conductor in which the current I returns along a number of parallel conductors, as indicated in Fig. 1, becomes:

$$\Phi = 0.2l\left[-\dot{I}_1 \log_e \frac{d_1}{r} - \dot{I}_2 \log_e \frac{d_2}{r} \cdots\cdots - \dot{I}_n \log_e \frac{d_n}{r}\right] \qquad (3)$$

where r stands for the radius of cross-section of the particular conductor which carries what will be thought of as the outgoing current I.

When energy is transmitted by polyphase currents, with any

FIG. 1.



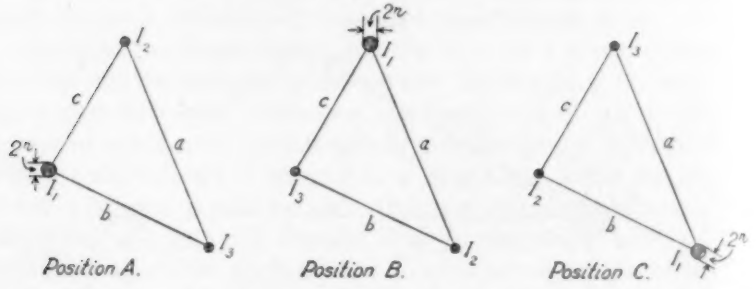
number of conductors, the algebraic sum of the currents in the conductors must, at any given instant, be equal to zero. Any one conductor may be looked upon as carrying the outgoing current, while the remaining conductors together carry the return current. Formula (1) can, therefore, be used for calculating the effective flux of induction surrounding any one conductor in a polyphase transmission, whatever may be the arrangement of the conductors. Obviously, the phase relations between the several components of flux must be taken into account, so that it is the vectorial sum of the quantities in the formula that is required.

Effect of Transposing Conductors of Three-phase Transmission.—When the conductors of a three-wire, three-phase transmission are not equally spaced, that is to say, when they do not occupy the corners of an equilateral triangle, the IX drop (or induced e.m.f.) will not be the same in all three conductors. If each conductor of such a transmission line is made to occupy, in turn, the positions originally occupied by the remaining two

conductors for a distance equal to one-third of the total distance of transmission, it is obvious that the out-of-balance effect will be corrected.

Fig. 2 shows the arrangement of three conductors with unequal spacings, a, b, and c. The three conductors carrying currents I_1, I_2, and I_3, respectively, occupy each of the positions (A), (B), and (C) over one-third of the total distance of transmission. Since the induced e.m.f. will necessarily be the same in the three conductors, it may be calculated by considering any one wire and

FIG. 2.



adding the flux components as calculated by formula (3) for each of the three positions indicated in Fig. 2. Consider the total flux which surrounds one centimetre length of the conductor carrying the current I_1 amperes:

$$\text{In position } (A),\ \Phi_1 = 0.2\left[-\dot{I}_3 \log_e \frac{b}{r} - \dot{I}_2 \log_e \frac{c}{r}\right].$$

$$\text{In position } (B),\ \Phi_1 = 0.2\left[-\dot{I}_3 \log_e \frac{c}{r} - \dot{I}_2 \log_e \frac{a}{r}\right].$$

$$\text{In position } (C),\ \Phi_1 = 0.2\left[-\dot{I}_3 \log_e \frac{a}{r} - \dot{I}_2 \log_e \frac{b}{r}\right].$$

One-third of the sum of these three flux values will be the average flux surrounding the conductor per centimetre of the entire length of the line, whence,

$$\text{Average flux per centimetre, } \Phi = \frac{0.2}{3}\left[-(\dot{I}_3 + \dot{I}_2) \log_e \frac{abc}{r^3}\right].$$

But in place of $-(\dot{I}_3 + \dot{I}_2)$ we may put I_1, and in place of $\frac{1}{3} \log_e \frac{abc}{r^3}$ we may put $\log_e \frac{\sqrt[3]{abc}}{r}$ whence,

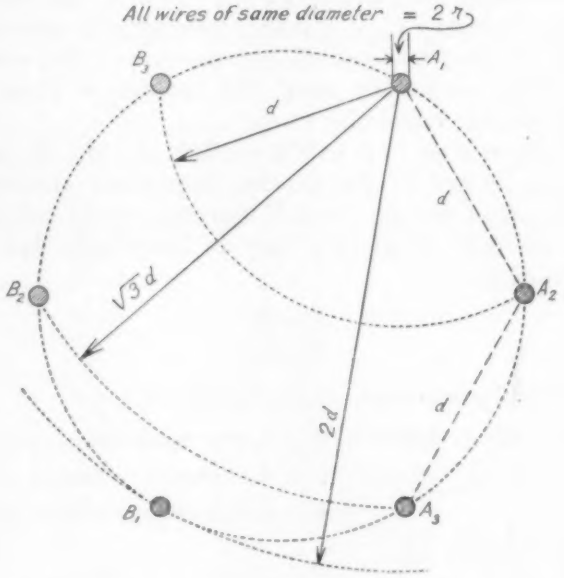
$$\text{Average flux per centimetre} = 0.2\, I_1 \log_e \frac{\sqrt[3]{abc}}{r} \text{ maxwells.}$$

This does not include the flux inside the material of the conductor, but if we substitute the "equivalent spacing" $\sqrt[3]{abc}$ for d in formula (2), the reactive voltage per mile in any one of the three wires of diameter $2r$ is

$$(IX) = 0.00466f\,I \log_{\epsilon} \frac{\sqrt[3]{abc}}{r} + 0.000506f\,. \qquad (4)$$

Thus, whatever may be the distances a, b, and c, between the

FIG. 3.



three points of support of a three-wire, three-phase transmission with wires regularly transposed, it is always possible to calculate the impedance of the transmission line by considering each of the three wires as one conductor of a single-phase circuit with the current returning by one or more imaginary parallel conductors at a distance equal to $\sqrt[3]{abc}$.

Inductance of Parallel Circuits as Affected by Position of Conductors.—By means of formula (3) it is possible to calculate the flux surrounding any one conductor of a power transmission line even when more than one circuit is carried on the same pole line. Fig. 3 shows the wires of two three-phase circuits occupying

the corners of a regular hexagon with equal sides of length d. These circuits are supposed to be in parallel and to be carrying a balanced load, so that the amperes of current will be the same in all six conductors. Owing to the symmetrical arrangement of the wires, with phase rotation in the same direction (1, 2, 3) in the two parallel circuits, the total effective flux around any one conductor will be the same (except in regard to phase) as that which surrounds any one of the other five conductors. The calculations for induced e.m.f. (or for resultant flux) may therefore be made for any conductor such as the one which carries the current A_1. In applying formula (3), it is merely necessary to remember that the current A_1 may be considered as the sum of five component currents which are exactly equal, but opposite in phase, to the currents in the five remaining wires.

Referring to Fig. (3), let the symbols A_1, A_2, A_3 stand for the currents in one of the parallel three-phase circuits, while B_1, B_2, B_3 stand for the (equal) currents in the other circuit Then $\dot{A}_1$ is equal to $\dot{B}_1$, not only in magnitude, but also in phase. Similarly,

$$\dot{A}_2 = \dot{B}_2$$

and

$$\dot{A}_3 = \dot{B}_3.$$

The several components of the current A_1 are:

$-(\dot{B}_3 + \dot{A}_2) = -(\dot{A}_3 + \dot{A}_2) = +\dot{A}_1$ returning at a distance d,

$-(\dot{B}_2 + \dot{A}_3) = -(\dot{A}_2 + \dot{A}_3) = +\dot{A}_1$ returning at a distance $\sqrt{3}d$,

$-\dot{B}_1 = -\dot{A}_1$ returning at a distance $2d$,

whence, by formula (3),

$$\Phi = 0.2l\left[A_1 \log_e \frac{d}{r} + A_1 \log_e \frac{\sqrt{3}d}{r} - A_1 \log_e \frac{2d}{r}\right]$$

$$= 0.2lA_1 \log_e \frac{\sqrt{3}d}{2r}. \qquad (5)$$

If two separate three-phase lines with a considerable distance between them were substituted for the arrangement of Fig. 3, the flux surrounding any one of the six conductors would be

$$\Phi = 0.2lA_1 \log_e \frac{d}{r} \qquad (6)$$

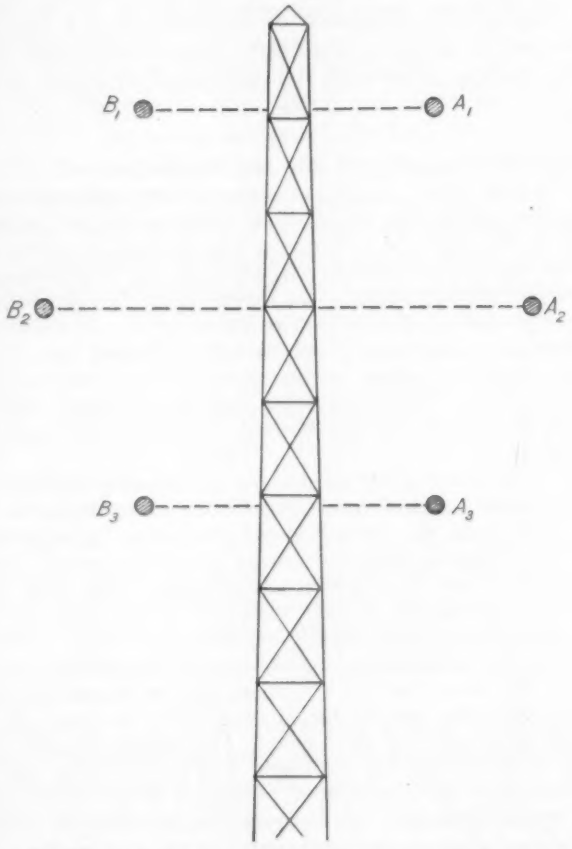
assuming the triangular (equidistant) arrangement with a separation d between wires. This is *greater* than the flux as given by formula (5). If we assume a distance $d = 120$ inches and the

radius of conductor cross-section $r = 0.4$ inch, the ratio of the induced e.m.f.'s for the alternative arrangements will be,

$$\frac{\log \frac{120}{0.4}}{\log \frac{\sqrt{3} \times 120}{2 \times 0.4}} = 1.025$$

Although, in this example, the reactive drop with the two

FIG. 4.



separate pole lines is only 2.5 per cent. greater than with all six wires on the same pole line, the fact remains that, with the proper arrangement of wires on a single pole line, two parallel three-phase circuits may be carried with a *smaller* reactive drop than if the two circuits are carried on separate pole lines with the same mini-

mum spacing between wires. This was pointed out by the writer sixteen years ago,[1] and H. B. Dwight has shown in a recent article [2] that if two parallel three-phase circuits are carried on the same pole line, the arrangement of Fig. 3 is decidedly preferable to the more usual arrangement of Fig. 4. By applying formula (3), it is easy to calculate the flux surrounding any one of the conductors, whatever may be the spacing between them, and when the circuits are arranged as in Fig. 4, it will be found that there is considerable unbalance of induced e.m.f.'s and that the average reactance drop is appreciably greater than with the phases arranged as in Fig. 3, or with the two circuits carried on separate pole lines.

Thermal Conductivity of Air and Hydrogen. E. SCHNEIDER. (*Ann. der Phys.*, No. 3, 1926.)—There are two general methods of measuring the coefficient of thermal conductivity of gases. One depends upon the cooling of a body by the transfer of its heat through the gas, the other, introduced by Christiansen and Schleiermacher and improved by S. Weber, requires the maintenance of a permanent state. The second is superior to the first in the reliability of its results, for by it all sources of error can be eliminated or allowed for. It is, however, strange that the second method gives higher values of the coefficient than the first. This difference may be connected with the use of only thin wires in the second method. In the present paper thinner wire is employed.

A wire is stretched along the axis of a circular glass tube containing the gas under examination. An electric current passes through the wire and from the resistance of the wire its temperature is inferred. The input of electrical energy also is measured. Surrounding the tube is a bath at constant temperature. The heat developed in the wire is conducted radially outward to the walls of the tube through which it proceeds, finally reaching the bath.

Nickel wires of diameters .4 and .1 mm., respectively, were used. The size of the wire had no effect on the coefficient of hydrogen, but with air the value got by use of the thicker wire was about 1 per cent. larger than with the thin wire. The values for the coefficient of thermal conductivity for hydrogen was found to be .001752 and for air with thick wire .0002477. Changes of pressure within the range of 11 to 458 mm. of mercury caused changes only in the seventh decimal place of the coefficient for air, and in the sixth place for hydrogen. The coefficient increases with rising temperature at the rate of .4 per cent. for air and .27 per cent. for H for each degree of rise. G. F. S.

[1] *Electrical World*, Sept. 15, 1910.

[2] *Electrical World*, Jan. 12, 1924.

NOTES FROM THE NELA RESEARCH LABORATORY.*

STROBOSCOPIC OBSERVATIONS OF A GEISSLER TUBE.

By E. W. Tschudi.

A HELIUM-FILLED Geissler tube, excited by a 60-cycle transformer, has been examined with a sector of three openings which rotated at such a speed that the light from one-half of the tube was eclipsed nearly sixty times a second. When the frequency of the eclipses differed from that of the exciting current by a very small amount, the purple glow about the electrode vanished and appeared with a frequency range of one-fourth to four, depending upon the speed of the sector. As the purple glow disappeared, the cream-colored light from the capillary spread into the bulb of the tube in the form of a cone which had the disc-shaped electrode for a base when the purple glow had entirely vanished. As the purple glow appeared again, the cream-colored cone shrank into the capillary. The frequency with which this cone made its appearance was equal to that of the disappearance of the purple glow, and *vice versa*. At the time when the purple light had disappeared (and when the cream-colored cone was complete) there was no excitation between the electrode and the end of the bulb under observation.

The illumination in the capillary at no time vanished, but a close examination of this portion of the discharge disclosed a small fluctuation in its intensity. The frequency of these fluctuations was twice that of the purple glow. At the times when the cream-colored cone was completely formed and again when it had entirely receded into the capillary, the intensity of light in the capillary itself was a minimum.

The capillary was next examined with a rotating mirror. When viewed through the stationary sector, the broad band of light seen in the mirror was crossed by dark lines at regular intervals, due to the passage of the exciting current through its zero values. There was no change in the appearance of these dark lines when the sector was rotated at the proper speed.

The explanation of the phenomena just described is attributed to the dual nature of the discharge. During each cycle of the alternating current, one electrode is first an anode and then a

* Communicated by the Director.

cathode, while the other electrode is a cathode and then an anode. When the purple glow is present, the electrode is a cathode, and when the cream-colored cone has made its appearance the electrode is an anode.

The probable explanation of the apparent persistence of illumination in the capillary when viewed through the rotating sector, while the rotating mirror showed that the radiation did vanish as the exciting current passed through the zero value, lies in the fact that the sector openings were so wide (30° each) as to permit the retina to receive and sustain the image of the illuminated capillary while the current passed through the zero value. A sector with narrower openings would have shown, no doubt, the stage of no excitation.

THE EFFICIENCY OF NEON LIGHT.

By Richard Rudy.

CONSIDERATIONS of the glow discharge as a light source, which different authors made some years ago, led to the conclusion that the efficiency was small, chiefly on account of space charge and on account of impacts causing "dark" transitions. Neither of these objections holds entirely. On one side, space charge may be reduced by using substances emitting electrons and positive ions at the same time, such as certain hydrides or by adding the iron catalysts. Ca seemed to give satisfactory results in the present work. On the other hand, excited atoms do not necessarily lose their energy in collisions with other molecules; the mercury atom in the $2p$ state can make hundreds of collisions with inert atoms without its radiating energy being transformed into heat. Neon offers another example. The intensities of the neon lines have been measured by different authors (Dorgelo, Meissner) and agree well enough except, as may be expected, for the shorter waves. From the visibility of the lines, their excitation potential and the mechanical equivalent of light the following efficiency may be deduced:

Positive column (high current density)	1.23 sph. cdl./w.
Positive column (low current density)	1.78 sph. cdl./w.
Negative glow	2.12 sph. cdl./w.
Low-voltage discharge	1.97 sph. cdl./w.

These values assume that the exciting electron has closely the velocity corresponding to the resonance potential, as is very nearly

the case in the positive column. The efficiency actually observed not only reaches, but even exceeds, the expected value. The conclusion is thus justified that in the case of neon at a few mm. pressure collisions with other atoms do not necessarily destroy the excited state of the atom. For the usual frequencies the radiation emitted by a cylindrical tube is closely proportional to the watts consumed. For high-frequency current or direct current, a higher efficiency may be expected and is obtained, at least for larger current densities and pure gas, because the excitation then starts from the metastable s_3 and s_5 states. Their existence is the reason why the color of the light may change with temperature. If the discharge could be completely carried by these metastable atoms, over 10 candles/watt could be expected. There is, however, a limit in trying to reach this state by increasing the current density, for instance, because the average energy of the electrons usually becomes lower and the efficient yellow and green lines grow fainter. This can be compensated for by varying the pressure, by increasing the length of the tube or by reducing the diameter of the tube, although production of heat and strong absorption set in beyond a certain limit.

As spectrograms have shown, sections of different diameters give different colors, because the average energy of the electrons is a function of the diameter. This circumstance, more directly than the higher current density, explains why mercury mixed with neon may show mercury lines only in large sections and neon in wider sections, or a mixture of both. In the present experiments, with a few mm. pressure, tubes of 20 to 30 cm. and 4 to 5 cm. diameter gave no positive column at all.

With small diameters the light becomes of a more yellow color, which recalls the positive column in very pure nitrogen. Finally, the ionization becomes so intense that the positive column is quite independent of the electric field. Wherever the electrons acquire high velocity, where they are able to ionize (cathode glow, or anode glow if it exists), the light is found to be of a more yellow color; it may then happen that the positive column shows traces of Hg vapor present, but not the negative glow. Mercury vapor often showed up in certain sections of a tube, but not in others, provided the diameters were different. This is not always considered if tests for impurities in an inert gas are made,

the resonance potential of which is markedly smaller than the neon terms.

ON ACTIVE NITROGEN II.

By Richard Rudy.

THE lines which belong to the neutral nitrogen atom were established only a short time ago. As a result of some other recent publications, the spectrum of the nitrogen discharge tube was once more examined and then compared with the spectrum of a tube filled with N_2 and He at several cm. pressure. The latter gave a faint afterglow, and all the strong N atom lines were present in the discharge. The afterglow was deep orange, as is usually the case at higher pressure. A second bulb was filled with the gas mixture at a lower pressure, and it gave a very strong afterglow; the spectrograms taken showed only He lines and nitrogen bands in the discharge. The discharge through nitrogen gave a strong afterglow, but showed no lines due to the atom, and even when a new discharge was sent through the gas, while the afterglow was still strong, none of the atomic lines were excited. The energy of the electrons, sufficient to cause the emission of the fourth positive group (14.8 volts), is sufficient, however, to excite the nitrogen lines as the ionization potential is about 14.5 volts. It may be added that strong afterglow is also obtained at low pressure where a dissociation is not likely to be produced.

On the other hand, evidence that metastable states exist in the excited nitrogen may be seen in the following facts. Owing to its position in the periodic system, nitrogen ought to be colored and possibly even a solid body. Before spectroscopic evidence was available, chemists therefore assumed that the electrons in the nitrogen molecule were distributed in two shells, one with 2 and the other 8 electrons. Both shells can give metastable terms, as the inner quantum number rule is usually obeyed. The three components of the nitrogen triplets are indeed influenced quite differently by external factors as if the different terms were subject to the disturbance for a quite different length of time. Whereas their relative intensity used to be 1 : 1 : 1, Toussaint obtained the ratio 8 : 7 : 5 by introducing argon, the component with the longer wave-length being strongly enhanced (just as the lines $2p - 2s$ in mercury vapor). A similar result can also be obtained by introducing self-induction, that is probably by

using a high-frequency discharge, which seems most suitable also for exciting strong afterglow. Of all the series lines P_2 and Q_2 are the only ones emitted; as far as the spectrograms allow a conclusion, these are probably the same lines that are influenced by argon. Finally, no emission has as yet been observed, corresponding to the transfer from the first excited state to the fundamental state. It is still possible that this constitutes an " obscure " transition. The Zeeman effect which could decide this question has been observed only on some of the lines. The bandheads 5959, 5906, 5855, the only lines studied definitely by F. Croze, yield a triplet corresponding to an sp_2 transition. The second positive group does not show the Zeeman effect, quite contrary to what might be expected if the group of bands are really related as are electronic levels in the same atom.

The new views on the structure of molecules fail to show, unfortunately, why the Zeeman effect is observed in some bands (halides of the alkaline earths, fluoride of Si, NO, doublet bands having large p separations) and not in practically all the others as if they were all $'S'S$ transitions. A difference between atoms and molecules might be expected as in the molecule the electron moves under the influence of positive charges at both foci of the orbit, and it is remarkable that in all the molecules, which give the Zeeman effect, the fluorides excepted, the electron moves under the influence of one of the atoms only as is evidenced by the doublet separation.

Bands corresponding to the first excitation stage have been observed in CO, but CO in contrast to N_2 also emits infra-red bands. Despite the analogy in the band spectra, which is such as to allow confusion, different types of electron orbits seem to exist besides in the nitrogen molecule, which are not to be distinguished by mere energy calculations. Some experiments were also made with liquid air surrounding the tube filled with glowing nitrogen. Instead of dying out in a flash, as some authors have stated, the afterglow lasted for many seconds; its duration was only slightly shorter than at room temperature.

ON THE PREVENTION OF VIBRATIONS.

By Richard Rudy.

ABSORPTION of vibrations in instruments is usually accomplished by trials, but the elementary theory gives some useful

hints. If a heavy support is vibrating according to the law $z = \frac{a}{f} \sin wt$ (where z is the displacement, f the elastic force, $\frac{a}{f}$ the amplitude, w the pulsation, t the time), and an instrument be placed upon it which will follow the vibrations as a whole or in part, m being the mass, the customary procedure is to place the instrument on blocks of rubber or felt. But a greater stability of the vibrating parts is usually attained by suspending the apparatus with suitable springs. There are then essentially two factors which determine the amplitude of the forced vibrations: The ratio d of the imposed frequency to the natural frequency, and the log decrement L of the forced oscillation of the vibrating part. Its motion is $z' = p \sin (wt - e)$ where $p = \frac{a}{\sqrt{(f - mw^2)^2 + h^2w^2}}$ and h is the coefficient of friction.

The ratio R of the new amplitude z' to the original amplitude z is

$$R = \frac{1}{\sqrt{(1 - d^2)^2 + \frac{4L^2}{\pi^2 + L^2} d^2}}.$$

When L is not considerable, R exceeds unity for all cases $d < 1$, that is the vibration is amplified instead of reduced by the use of spring supports. But R decreases for $d > 1$, and the decrease is the more marked the better the damping. With $z'_n / z'_{n+1} >$ about 5, the original vibration is not amplified any more whatever d. Hence, only in cases where the frequency of the system (formed by the instrument and the spring suspension) is above the forced frequency, can vibrations be reduced without much damping. The importance of damping is then evident; it can be introduced by having parts of the supported system rub against parts of the support.

Where this is not possible and where adding weight to the supported system is objectionable (as in the case of springs to be prevented from vibrations), advantage may be taken of the fact that some friction being always present, a difference in phase exists between the force and the motion, $\tan g\, e = \frac{wh}{f - w^2 m}$. That is, the vibrating part is acted upon by the elastic force with the corresponding elongation z' coming some time afterwards only. But the same part is also subject to the vibrations of the spring

support itself. If now both impulses produce at the same time the same displacements, but of opposite sign, the vibrating instrument part will stay quiet. e indeed may become negative $e = arctg \frac{2L}{\sqrt{\pi + L^2}} \frac{d^2}{1 - d^2}$. This case could be observed on incandescent lamp filaments, where d exceeded unity as required by the theory.

If the mass of the instrument is comparable with the mass of the vibrating support, the two systems react upon each other and the more general case of coupled oscillations will have to be considered.

The Largest Optical Flats in the World.—Surfaces so flat that any deviation from perfectness is too small for measurement have been produced by the United States Bureau of Standards, and henceforth will be the final word in deciding whether or not a surface really approaches flatness or straightness. The discs, or optical flats, will not be used for direct comparisons but as master flats for checking the accuracy of the optical discs which are used in the work of the bureau. Measurements on the surfaces of these discs, from ten to eleven inches in diameter and one to one and one-half inches thick, fail to show any places where they are more than two ten-millionths of an inch from being absolutely flat. Such accuracy means that, magnified until the discs extended from Washington to Chicago, no point except along the margin would be out of absolute flatness by more than an inch. These flats are clear fused quartz, produced in the Thomson Research Laboratory of the General Electric Company at Lynn, Mass. The product, commercially introduced two years ago by the company, has many properties which make it superior to optical glass. It is much harder than glass and it expands much less than does glass upon being heated. The surface of glass, formerly used for optical flats, changes considerably in shape when touched by the hand, so sensitive is it to heat. Clear, fused quartz, which expands only one-fifteenth as much as does glass upon being heated, can be handled with much more impunity in this respect. The low coefficient of expansion of clear fused quartz also recommends its use for astronomical mirrors and for the manufacture of standards of length. Its resistance to change at high temperatures has led to its use in the manufacture of thermometers which can be used at far higher temperatures than can be approached with glass ones.

In addition to serving as a test for flatness of surfaces and straightness of edges, these standards are used in the production of standard angles and for calibrating or checking instruments that measure curvature. H. L.

Determination of Free Chlorine in Air.—LYMAN E. PORTER, of the University of Arkansas (*Ind. and Eng. Chem.*, 1926, **18**, 730–731), recommends the following procedure for the colorimetric determination of free chlorine in air. By means of an aspirator, a definite volume of air is drawn, at not too rapid a rate, through 10 c.c. of a solution of orthotolidine (1 gram of orthotolidine dissolved in 100 c.c. of concentrated hydrochloric acid, then diluted with water to a volume of 1 litre) contained in a test tube. The contents of this tube are then transferred to a tall-form Nessler tube; the test tube is rinsed with water, and the rinsings added to the Nessler tube, the contents of which are then diluted to the mark. After standing for at least two minutes, the color of the unknown is compared with permanent colorimetric standards, which are prepared by mixing in definite proportions two standard solutions, one containing cupric sulphate, the other containing potassium dichromate and sulphuric acid. The chlorine content of the air is finally expressed as parts per million. J. S. H.

Use of Isopropyl Alcohol in Analytical Chemistry.—H. A. SCHUETTE and LOYD E. HARRIS, of the University of Wisconsin (*Jour. Am. Pharmaceutical Asso.*, 1926, **15**, 166–169), have used purified isopropyl alcohol (isopropanol, boiling-point 81.3° C. uncorrected) as a solvent for potassium hydroxide in the determination of the saponification number of oils, fats, and waxes. The results were comparable with those obtained by the use of alcoholic potash (solution of potassium hydroxide in purified ethyl alcohol) according to the official method of the Association of Official Agricultural Chemists. The new procedure is characterized by rapid saponification, and has certain additional advantages. The reagent apparently is less subject to the disturbing effect of formation and resinification of aldehydes; and the solvent is not subject to legal restrictions with respect to its sale or use.

Schuette and Harris (*Jour. Am. Pharmaceutical Asso.*, 1926, 15, 169–173) also report that a solution of potassium hydroxide in isopropyl alcohol possesses possibilities as a substitute for glycerol-potash or alcoholic potash in the saponification of fats and oils as a preliminary to the titer test, *i.e.*, the determination of the solidifying point of their insoluble fatty acids. J. S. H.

Chemical Industries in India.—H. E. WATSON (*Ind. and Eng. Chem.*, 1926, **18**, 748–752) describes concisely the present status of the chemical industries in India. Among the products of India are: Iron, lead, silver, gold, salt, saltpetre, cement, heavy chemicals, paints, soap, sugar, shellac, vegetable dyes, alcohol, quinine, opium, essential oils, vegetable oils, mineral oil, and the products of the distillation of wood. J. S. H.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

RETINAL SENSIBILITY TO SATURATION DIFFERENCES.[1]

By L. A. Jones and E. M. Lowry.

OF THE three attributes of color, brilliance, hue, and saturation, the latter has probably been accorded the least attention. The present work was undertaken for the purpose of obtaining specific data on this subject. Using a modified Nutting colorimeter the sensibility of the eye to saturation differences was determined for the following colors: Blue, blue-green, green, yellow, orange, and red. The number of equal sensation steps was found to vary for different colors. Saturation scales were constructed by integrating the sensibility curves. Illustrative data will be presented and discussed.

The Law of the Resistance Met by Spheres Moving Rapidly in Water. W. BAUER. (*Ann. der Phys.*, No. 11, 1926.)—From a horizontal gun barrel bullets were shot through a vessel containing water and the loss of velocity thereby caused was measured by electrical means. The sides of the water vessel were made of paper and offered little resistance to the projectile. Their distance apart could be changed so as to vary the length of the path in water. Deformation of the projectile was avoided by using a smooth and not a rifled bore, and by employing steel spheres. Their diameter was 11 mm. A new ball was used for every shot because the stopping arrangement scarred the ball. By graduating the quantity of powder used, the speed was controlled. Its maximum value was 650 m. per sec. and the minimum 150 m. per sec.

After leaving the muzzle of the gun the ball traverses openings in two screens that serve to keep the explosion gases from the rest of the apparatus. It then passes between the parallel sides of a hairpin made of glass-hard steel wire. This breaks, and by so doing starts the discharge of a condenser, the electrical charge of which is known, through a coil. Next the ball meets and breaks a second hairpin by which the discharge of the condenser is stopped. From the distance apart of the two hairpins and the quantity of electricity discharged while the ball is going from the first to the second the speed of the ball can be calculated. The ball then goes through the vessel of

* Communicated by the Director.

[1] Communication No. 254 from the Research Laboratories of the Eastman Kodak Company and published in *J. Opt. Soc. Amer.*, **13**: 25, 1926.

water and beyond it actuates a second pair of triggers similar to the hairpins on the other side of the water. Thus its speed before and after traversing the water is known. By examination it was found that the reduction of speed caused by breaking the paper sides of the water vessel and the triggers lay within the limits of experimental error. In addition 2 m. of air between the two triggers on opposite sides of the water vessel had to be passed through. This air caused a loss of .8 per cent. of the speed when it was 200 m./sec. and 2.3 per cent. when it was 600 m./sec. Three different thicknesses of water were used, each with a number of velocities. With the ball traversing 1.25, 2.95 and 8.15 cm. of water, respectively, the corresponding reductions of speed due to the water were from 643 to 606 m./sec., from 647 to 583 m./sec. and from 629 to 488 m./sec. For each length of path in water the speed at exit was the same fraction of the speed at entering, no matter how great that speed was. This by mathematical interpretation leads to the conclusion that the resistance to the ball in water is proportional to the square of its speed.

G. F. S.

Can a Lead Wire Be Made to Emit Light? D. DAMIANOS. (*Phys. Zeit.*, May 1, 1926.)—As lead melts at 327° C. and as the emission of light begins somewhere above 500° C., it would seem impossible for lead wire in a free span to glow, yet the author actually came upon both lead and zinc wires that gave out light.

Two brass cylinders fitted snugly in a steel tube. Between them were stretched a lead wire of .62 mm. diameter and a somewhat smaller platinum wire. The length of each wire was 8 mm. A Bunsen flame was applied and through an aperture both wires were seen to glow. After cooling, the lead wire was found to be covered with a coating of oxide. When nitrogen carefully freed from oxygen flowed past the lead during the application of heat, the metal broke into drops. In another experiment he let a lead wire of the same diameter as the previous one, but 4 cm. long, hang free in a glass tube through which air flowed. An electric current traversed the wire and the resistance with increasing current was measured. At a certain current strength there was a sudden increment in the resistance and at the same time the middle of the wire sagged down. Further augmentation of the current produced more sagging and the middle of the wire became luminous. Upon repeating the experiment with a fresh piece of lead wire past which a current of nitrogen flowed, the author found the wire to melt at the current strength at which in the earlier experiment the sudden increase of resistance occurred. There was no emission of light. Thus it appears that the formation of a surrounding layer of oxide is necessary for the success of the experiment, that is, for heating a wire of liquid lead until it glows.

G. F. S.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

PROTEINS OF WHEAT BRAN.
III. THE NUTRITIVE PROPERTIES OF THE PROTEINS OF WHEAT BRAN.[1]

By J. C. Murphy and D. B. Jones.

A CHEMICAL study of the proteins of wheat bran having indicated that these proteins have a high nutritive value, the Protein Laboratory of the Bureau of Chemistry undertook a series of feeding experiments with rats to obtain further information on the biological value of the bran proteins and also to determine to what extent they are available for assimilation when the animals are fed not the isolated proteins, but the crude bran.

The experimental work showed that the proteins of wheat bran are characterized by a high content of the so-called "nutritionally essential" amino acids. The quantity of arginine and lysine in the globulin exceeds that found in most vegetable proteins which have been studied. The albumin also contains high percentages of tryptophane, tyrosine, and cystine. Taken collectively, the proteins of bran contain more than twice as much of these amino acids as are contained in the proteins of the same quantity of wheat endosperm.

The bran proteins are well utilized by albino rats when 70 per cent. of a ration, known to be adequate with respect to dietary factors other than proteins, consisted of washed bran from hard, spring wheat containing no detectable quantity of embryo and not more than 3 per cent. of the endosperm. Rats grew at an excellent rate for fifteen to sixteen weeks when commercial bran (unwashed) constituted the only source of protein in their ration. During the first six weeks of the experimental period the animals gained in weight an average of 1.83 gm. per gm. of crude protein eaten.

When patent wheat flour supplied the sole source of protein in a similar ration, rats grew during the first fifteen to sixteen weeks at a rate of only one-half to two-thirds of that shown by the rats

* Communicated by the Chief of the Bureau.

[1] Published in *J. Biol. Chem.*, **69**, No. 1, July, 1926, pp. 85–99.

receiving the bran. Their gain in weight per gm. of protein eaten (NX 5.7) was 0.88 gm. Although the bran ration was very efficient for the promotion of growth in young rats during the first fifteen or sixteen weeks, for the subsequent forty-eight weeks only little better than maintenance of body-weight resulted.

Rats fed the bran diet produced offspring, but they had little success in rearing them. Fecundity was low.

SUBSTANCES WHICH AFFECT PHOTOGRAPHIC PLATES IN THE DARK.[2]

By George L. Keenan.

[ABSTRACT.]

THE effect which some substances have on photographic plates in the dark has been studied and a comprehensive review of the literature made. Experiments conducted in the Bureau of Chemistry and also carried on by previous workers showed that emanations proceeding from the active substances were actually responsible for the results obtained. It seemed evident that both oxygen and moisture had to be present to produce a darkening of the plate. As hydrogen peroxide could not be produced in their absence, the view that this compound is the active agent seems inescapable. However, these considerations do not prove that hydrogen peroxide is the only substance that is active.

CONSTITUENTS OF CRUDE COTTONSEED OIL, PALMITIN, DI-PALMITIN, AND PHYTOSTEROLINE.[3]

By G. S. Jamieson.

[ABSTRACT.]

THE alcohol-soluble portion of the settlings which separate from clear, crude cottonseed oil has been studied further. Although the oil investigated had stood in the laboratory for about three years before the settlings were removed for the investigation, it was free from rancidity and in excellent condition.

Palmitin, amounting to about 25 per cent., and di-palmitin, amounting to about 1 per cent. of the total settlings, were iso-

[2] Published in *Chemical Reviews*, 3: 95–111, April, 1926.

[3] Published in the *Jour. Oil and Fat Ind.*, 3, No. 5, May, 1926.

lated and identified. About 0.1 per cent. of a phytosteroline, which gave an acetyl derivative melting at 166° to 167° C., was obtained.

It appears from the results of this investigation that the di-palmitin, which was probably produced by the hydrolysis of a very small quantity of a tri-glyceride, accounts in part for the acetyl value obtained with cottonseed oil. As no investigation has succeeded in showing the presence of any hydroxy acids in cottonseed, or for that matter in many other oils giving a comparatively small acetyl value, the values noted may be largely due to the presence of small quantities of various di-glycerides.

SOIL REACTION IN RELATION TO HORTICULTURE.[1]

By E. T. Wherry.

[ABSTRACT.]

TERMS are defined, the various methods of stating reactions which have been proposed are discussed, and the methods of measuring soil reaction now available are described. For stating reaction it is urged that some plan other than the logarithmic pH values be used, and active acidity and active alkalinity values are suggested, the correspondence between these and pH being shown by a table. Descriptive terms—superacid, mediacid, subacid, and minimacid—are shown to be useful for covering certain reaction ranges.

As most plants of horticultural interest are divisible into two groups, those preferring circumneutral soils and those preferring soils of high acidity, a one-indicator method of testing soils as to their reaction should be sufficient for many horticultural purposes. Bromcresol purple is regarded as most suitable, because its marked color change occurs at the value pH 6 or active acidity 10, dividing the two groups. For more precise work, multiple indicator and comparator methods are required.

About 300 plants found in the horticultural trade or otherwise available to gardeners have been arranged according to their apparent soil acidity preferences. Plants not included are to be inferred to prefer circumneutral soils, so that the lists given

[1] Published as Bulletin 4, American Horticultural Society, May, 1926.

furnish a complete guide for horticulturalists in the field of soil reaction.

THE MECHANISM OF STAIN ACTION WITH BASIC DYES.[5]

By Walter C. Holmes.

[ABSTRACT.]

THE chemical theory of staining is discussed in the light of recent discoveries respecting the mechanism of the reaction of basic dyes with substances of an acid character. It is shown that staining may result through the formation of addition products as well as through the formation of dye salts.

FLUORESCEIN DYES AS BACTERIAL STAINS.[6]

WITH SPECIAL REFERENCE TO THEIR USE FOR SOIL PREPARATIONS.

By H. J. Conn,

New York Agricultural Experiment Station,

AND

W. C. Holmes,

Color Laboratory, Bureau of Chemistry.

[ABSTRACT.]

ERYTHROSIN and rose bengal have been suggested in the past as bacterial stains, particularly in the direct study of microorganisms in soil. The writers made a further investigation of these two dyes and others of the same group (thirteen in all) to determine their relative merits for this purpose. It was found that practically all the deeper dyes of the group stain bacteria in pure culture satisfactorily, but that in the case of soil infusions some of the dyes have such an affinity for the dead organic matter as to obscure the bacteria present. Best results were obtained with rose bengal B, but good staining effects may be obtained with the phloxines and erythrosins. The behavior of any one of these dyes when applied to a soil preparation varies according to the reaction of the material stained. This is mentioned as a possible explanation as to why others have found better results with erythrosin than with rose bengal.

[5] Published in *Stain Technology*, 1, No. 3, July, 1926.

[6] Published in *Stain Technology*, 1, No. 3, July, 1926.

NOTES FROM THE U. S. BUREAU OF MINES.*

FOURTEENTH SEMI-ANNUAL MOTOR GASOLINE SURVEY.

By E. C. Lane, J. M. Devine, and Peter Grandone.

THE motor gasoline which is being marketed in the United States this summer is apparently more volatile than the gasoline sold a year ago. In fact, the average volatility of this summer's gasoline is almost the same as the average volatility of the gasoline marketed last winter.

During the past seven years the Bureau of Mines has made semi-annual surveys of the gasoline marketed in the United States, the survey just completed being the fourteenth in the series. The cities in which samples have been collected have been chosen as representative of the more important marketing territories, as it is obviously impracticable to obtain a sample of every gasoline sold in the entire country.

A summary of the results of the fourteen surveys indicates that particularly at the lower end of the distillation range and at the end point the average gasoline marketed this summer is better than that shown in any of the previous " summer " surveys. However, the central and upper parts of the distillation range, as shown by the 50 per cent. and 90 per cent. points, are not far different from those of gasoline previously marketed. A detailed study of the individual analyses indicates that this improvement in quality is due to two factors, first, to a larger percentage of samples with relatively low initial and end points and, second, to an improvement in the volatility of some of the benzol blends marketed in different parts of the country.

In the past there has apparently been a distinct difference between " summer " and " winter " gasoline, that marketed during the winter being more volatile than that sold during the summer. This year there is very little difference between " winter " and " summer " gasolines.

Distillation curves and detailed tables on the results of the distillation tests are presented in Serial 2765 of the Bureau of Mines, recently published.

* Communicated by the Director.

PROBLEMS OF THE GAS MANUFACTURING INDUSTRY OF CALIFORNIA.

By W. W. Odell.

A STUDY of certain gas-making and fuel problems, peculiar to the gas industry of California, has been made by the Bureau of Mines. In the northern, or San Francisco Bay district, the gas distributed is almost exclusively manufactured by the oil-gas process, using oil as fuel, and in the southern, or Los Angeles district, the gas is, for the most part, a mixture of natural gas and manufactured gas, but oil is the principal fuel used in gas-making when natural gas is inadequate. As all the companies are equipped with apparatus to use oil fuel, the industry desired to know what effect future conditions might have on the process, and what would be the most economical process for future use, if a continued supply of low-priced oil were not available. The work was done in coöperation with the California Gas Research Council, an association of the manufacturers. Basic information was obtained on the gas-making fuels available to California, and the possibility of efficiently utilizing fuels in making gas by other processes than the oil-gas process. The information is being used by the gas industry of California in developing a program for future construction.

OCCURRENCE, MINING AND MILLING OF MICA.

By W. M. Myers.

DURING the month deposits of mica in Southern California, Arizona, New Mexico, and Colorado were examined. Particular attention was given to western mining and milling practice, and to western market conditions. This completes the field study of mica, covering the principal deposits of the United States. The object of this investigation was to determine the most efficient methods of mining and milling of mica, with a view of their wider application in the industry, and the elimination of waste.

TEMPERATURES IN GAS LINES.

By E. L. Rawlins.

THE bureau has completed a study of temperature fluctuations of natural gas flowing in unburied pipe lines, as compared with the temperatures in pipe lines covered with earth. Valuable data

were obtained which will serve as a basis for explaining differences in leakage rates from covered and uncovered lines, in so-called "breathing losses" in pipe lines carrying gasoline, and in correcting apparent errors in measurements of natural gas. While the tests were conducted only in one district, the data indicate the general effects of temperature variations in other parts of the country. Further study is needed to establish the exact depth of cover required to offset undesirable fluctuations of temperature under different conditions.

CONSUMPTION OF REAGENTS USED IN FLOTATION.

By Thos. Varley.

DATA were assembled on the consumption of reagents used in metallurgical plants treating minerals by flotation, during the year 1925. The bureau's figures show that flotation practice is being developed rapidly and on a more scientific basis than ever before. The total quantity reported of ore milled in 1925, including miscellaneous non-metallic materials, was 59,370,177 tons, and most of this ore was put through flotation plants, the amount so treated being 45,490,331 tons. The Bureau of Mines is closely coöperating with the operators, and is following a well-laid-out program of research on the fundamental principles of flotation. The data gained in the laboratory work are applied by technical research men in commercial plants, and the direct results obtained have been of material benefit to the industry in many ways.

New Abstract Journal.—*Biological Abstracts* is announced as "a comprehensive abstracting and indexing journal of the world's literature in theoretical and applied biology exclusive of clinical medicine." It succeeds both *Abstracts of Bacteriology* and *Botanical Abstracts*. In addition to the various divisions of botany and zoology, sections are also devoted to such subjects as paleontology, biochemistry, biophysics, pharmacology, immunology, insecticides and insecticidal apparatus, and applied microbiology. The new abstract journal begins its work with the literature of 1926. Twelve monthly issues and an index number will constitute a volume coinciding with the calendar year. Published under the auspices of The Union of American Biological Societies, the new journal has its editorial office at the University of Pennsylvania. J. S. H.

Whisky.—In his annual report on food products and drug products for the calendar year 1925, E. M. BAILEY (*Conn. Agric. Exp. Station Bull. 276*, 1926, pp. 389–392) discusses the composition of samples of whisky collected under the liquor laws during the period 1920–1925. The alcohol content of 274 samples ranged between 16.40 and 59.60, with an average value of 42.40 per cent.; but nine samples contained less than 30 per cent. The samples, as a rule, did not contain an excess of solids. Of 90 samples tested with respect to their color, but seven had a natural color; the other samples contained caramel, and one of them a coal-tar dye also. The odor and taste of the residue on evaporation was determined on 78 samples; judged by this test, only six samples were genuine. Sixty samples were tested for the presence of denaturants; diethyl phthalate was found in 26 samples, isopropyl alcohol in one sample; wood alcohol was not found in any of the samples. A series of 123 samples of bar whisky, chiefly cheap grades, had been analyzed in 1915, prior to the advent of prohibition. The average alcohol content and the proportion of artificially colored samples were approximately the same in the two series. The only significant difference between the two series was the frequent occurrence of denaturants in the present-day product, due to the source from which its alcohol is derived. The concluding paragraph of this section of the report is as follows: "The possibility of clumsy manipulation of denatured alcohol in order to make it fit for beverage purposes constitutes a menace to health which cannot be ignored. This applies not only to whisky, but to similar liquors, *e.g.*, gin, brandy, and cordials, of high alcohol content, all of which may be produced factitiously." J. S. H.

Oxides of Potassium and Sodium.—CHARLES A. KRAUS and EARLE F. WHYTE (*Jour. Am. Chem. Soc.*, 1926, **48**, 1781–1790) have studied the oxidation of the alkali metals at the temperature of liquid ammonia. The metal (potassium or sodium) was dissolved in liquid ammonia, and a current of oxygen was passed through the resulting solution. On slow oxidation of potassium, the hydroxide and the amide were the initial products of oxidation; further oxidation converted the amide into the hydroxide and the nitrite. On rapid oxidation of potassium, the initial product was the dioxide, K_2O_2, which was converted into the tetroxide, K_2O_4, on further oxidation. Potassium trioxide, K_2O_3, was not formed by this method of oxidation. However, the tetroxide underwent a reversible dissociation at temperatures above 300° C.; the final product of dissociation had a composition corresponding to that of the trioxide.

When sodium was subjected to slow oxidation, its products corresponded to those yielded by potassium under similar conditions. On rapid oxidation, sodium yielded its dioxide, Na_2O_2. No evidence was obtained of the formation of the trioxide, Na_2O_3. J. S. H.

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LIBRARY NOTES.

RECENT ADDITIONS.

ALEXANDER, JEROME, Editor.—Colloid Chemistry: Theoretical and Applied, by selected international contributors. Vol. 1. 1926.

American Concrete Institute.—Proceedings of the Twenty-second Annual Convention, 1926. Vol. 22. 1926.

American Foundrymen's Association.—Transactions. Proceedings of the Twenty-ninth Annual Meeting, 1925. Vol. 33. 1926.

American Gas Association.—Proceedings, Seventh Annual Convention. 1925.

Annuaire Sucrier, 1926.

BLOCH, LÉON.—Ionisation et Résonance des Gaz et des Vapeurs. 1925.

BOESEKEN, J.—Configuration of the Saccharids. Vol. 2. No date.

CLAPEYRON, E.—Abhandlungen über die Bewegende Kraft der Wärme. Ostwald's Klassiker der exakten Wissenschaften Nr. 216. 1926.

DOBSON, G. M. B.—The Uppermost Regions of the Earth's Atmosphere. 1926.

Faraday Society.—Photochemical Reactions in Liquids and Gases: A General Discussion. 1925.

FRESNEL, A. J.—Abhandlungen über die Beugung des Lichts. Ostwald's Klassiker der exakten Wissenschaften Nr. 215. 1926.

HATSCHEK, EMIL, Editor.—Klassiche Arbeiten über kolloide Lösungen. Ostwald's Klassiker der exakten Wissenschaften Nr. 217. 1926.

HETZEL, FREDERICK V.—Belt Conveyors and Belt Elevators. 1926.

Minerva, Jahrbuch der gelehrten Welt. Jahrgang 28. Three volumes. 1926.

National Research Council of the United States of America.—International Critical Tables of Numerical Data, Physics, Chemistry and Technology. First edition. Vol. 1. 1926.

Nelson's Perpetual Loose-leaf Encyclopædia. Index Number. 1926.

NOYES, WILLIAM ALBERT.—Organic Chemistry. 1926.

Royal Society of Edinburgh.—Transactions. Vol. 54, Part 2. 1926.

Royal Society of London.—Philosophical Transactions. Series B. Vol. 214. 1926.

Society of Chemical Industry.—Annual Reports on the Progress of Chemistry. Vol. 10. 1925.

BOOK REVIEWS.

COLLOID CHEMISTRY: THEORETICAL AND APPLIED. By selected international contributors. Collected and edited by Jerome Alexander. Volume 1. Theory and Methods. 974 pages, 8vo, many illustrations. New York, The Chemical Catalog Company, 1926. Price, $14.50.

This is the latest word on the great department of physical chemistry that has developed from Graham's work about the middle of the last century. To review it properly would require a collaboration of critics. Andrew Lang once

suggested that authors should establish a magazine for the reviewing of their own books. He remarked that generally, indeed almost always, all that reviewers read is the preface, and inasmuch as the author has necessarily read his own book, he is most competent to pass judgment on it. Andrew was in fun, of course, but it is true that book reviewing in the scientific field is becoming more and more a matter of form, owing to the increasing specialization. It seems, indeed, to the present reviewer that the best judgment on the book might be obtained if the several collaborators would join in a review, each taking some other article than his own. Although it is true that specialization has been carried so far that even in the field of colloid chemistry there are many data which are not known to all workers, or even to very few, yet there must be considerable overlap in knowledge and each contributor could apply this knowledge in judging of merits of a given essay.

Turning to the details of the book, it is made up of articles by about threescore contributors, drawn from many countries and written in many languages, though, of course, translated. Noteworthy is the fact that a well-known member of The Franklin Institute, Doctor Creighton, is one of the contributors. Curiosity is aroused by an article by Hsien Wu, Professor of Biochemistry, Peking Union Medical College, and Daisy Yen Wu, A.M. Does this mark the entrance of a native-born celestial of the fair sex, or is it a case of a companion from the western world? "Daisy" does not seem to be Chinese.

The work is to appear in three volumes. The second and third are to cover, respectively, "Biology and Medicine" and "Technology." The work had its inception in 1922, when Mr. Turner, Technical Editor of the Chemical Catalog Company, asked Mr. Alexander to prepare a comprehensive book on colloid chemistry. It was suggested that it should be international, and we are told that nearly two hundred papers have been promised. Circumstances beyond the control of some of the contributors have prevented compliance with agreements, but the major portion of the contributions have already been received.

The initial article is by the editor on "The Submicroscopic Structure of Matter." This is followed by an article by Professor Weimarn, who is now in Japan, but the original text was in Russian. The translation is not entirely pleasing, the text being occasionally awkward, but its most serious defect is the excessive use of italicized words. It is to be regretted that the editor did not eliminate most of these, for very few are necessary or even permissible. A notable article is that by Friedel, of Strasbourg, on "The Mesomorphic States of Matter." This deals with the phenomena that O. Lehmann described in 1889 under the somewhat startling title of "Liquid Crystals." "Colloid Meteorology," by Humphreys, includes much interesting data concerning atmospheric phenomena and also studies of ice masses and frosts.

It would require, indeed, a small volume to set forth the extensive and varied information and instruction that is contained in the book. The editing of it must have been a work of great labor, but the editor is thoroughly familiar with colloid chemistry in all its phases, and an enthusiast in study and thus the book is a full report on the present state of this branch of physical chemistry.

HENRY LEFFMANN.

ORGANIC CHEMISTRY. By William Albert Noyes, Director of the Chemical Laboratory of the University of Illinois. xviii–677 pages, illustrations, 8vo. New York, Henry Holt and Company, 1926. Price, $3.50.

If a new manual on elementary organic chemistry is needed Doctor Noyes is eminently qualified to write it. The work covers the field of organic chemistry as generally presented in the textbooks on that subject. The author in the preface claims that textbooks on chemistry have been generally criticized in comparison with textbooks on physics because burdened with a very large amount of details without the presentation of fundamental principles. He holds this criticism to be just with regard to the general run of textbooks on organic chemistry. It does not appear to the reviewer that this criticism is well placed. The difficulty, as indeed Doctor Noyes notes, lies principally in the fact that organic chemistry presents us with an enormous number of compounds, the structure of which is based upon comparatively few types. The synthetic methods which have developed in organic chemistry have seemed to afford limitless extension and the numerous cases of isomerism produce a still further complication and multiplication of details.

So far as the arrangement of the book is concerned it follows the usual plan. Chapters on fundamental principles, substitutions, procedures of analysis, physical properties in general—all these are given full consideration. The descriptive text then begins in the usual way with the hydrocarbons followed by the more complex derivatives and the compounds containing nitrogen and sulphur. Considerable information is given as to the methods of synthetic processes. In later chapters the aromatic hydrocarbons are considered and then the text returns to the aliphatic series, discussing the alcohols and also the aromatic forms. A very large amount of information concerning all important departments of organic chemistry is to be found in the book which is printed in clear type, easily read, and the work will certainly be useful to the student of the subject.

HENRY LEFFMANN.

PHOTOCHEMICAL REACTIONS IN LIQUIDS AND GASES. 226 pages, 8vo, illustrated, limp cloth. London, The Faraday Society, 1925. Price, 15s. 6d.

This is the report of a discussion held in October, 1925, by the Faraday Society. Numerous papers were presented by experts; members and others participated in the discussion. Einstein's law of photo-equivalence, and the mechanism of photochemical reactions were the two phases of the subject which were discussed at length. A summary on the present position of photochemistry is given as a concluding essay by Doctor Rideal. It appears from this that much difference of opinion exists concerning the mode of operation in photochemical processes. A critical examination of the Stark-Einstein law shows that the relation of quanta absorbed to the chemical action resulting is not constant. Some authorities reject the law entirely. Rideal discusses details of the phenomena in connection with the Bohr theory of the atom. As might be expected many details of the phenomena are still unexplained. The matter presented in the book is extremely technical, but very valuable as a contribution to research in an important field.

HENRY LEFFMANN.

CANADA, DEPARTMENT OF MINES, MINES BRANCH. Molybdenum: Metallurgy and Uses and the Occurrence, Mining and Concentration of Its Ores, by V. L. Eardley-Wilmot. 304 pages, illustrations, plates, maps, 8vo. Ottawa, King's Printer, 1926.

The author gives a historical review of the metallurgy of molybdenum. By means of tables and diagrams he compares the results achieved with it in various combinations with various other elements, and with steels free of molybdenum. Its use in the manufacture of wireless and electrical equipment is also increasing. As a substitute for platinum it is in demand, and its salts are required for certain chemical analyses.

The author points out that molybdenum ores are not nearly so scarce as was once believed, and over 350 Canadian occurrences of molybdenite, the chief ore of this metal, are tabulated conveniently and mapped for reference, and the majority of these are also described. The world's more important deposits are also briefly reviewed.

The concentration of molybdenum ores is discussed in detail and numerous flow sheets of Canadian, United States, Australian, Norwegian and other concentrators are given. Molybdenite is now known to be one of the easiest minerals to concentrate, unless the ore be very complex, by using any of the well-known methods of oil flotation. The report also contains an extensive bibliography dealing with references to all phases of the subject.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS. Report 223, Pressure Distribution on the C-7 Airship. By J. W. Crowley, Jr., and S. J. DeFrance. 41 pages, illustrations, quarto. Washington, Government Printing Office, 1926. Price, fifteen cents.

This investigation was made by the Committee at the request of the Bureau of Aeronautics, Navy Department, for the purpose of determining the aerodynamic pressure distribution encountered on a "C" class airship in flight. It was conducted in two parts: (*a*) Tests on the tail surfaces in which the pressures at 201 points were measured and (*b*) tests on the envelope in which 190 points were used, both tests being made under as nearly identical flight conditions as possible, so that the results could be combined and the pressure distribution over the entire airship obtained.

The method of testing consisted of measuring the pressures by means of orifices located at the desired points connected to the tubes of a multiple liquid manometer. Simultaneous readings of all the pressures were obtained by photographing the manometer.

The results as presented in this report are mainly in tabular form and may be briefly summarized as follows:

(1) The maximum local pressure encountered on a tail surface was 7.3 lb./sq. ft.

(2) The maximum total normal force on a complete tail surface was 352 pounds or a C_{NF} of 0.316 occurring on the bottom fin and rudder during a "reversal" of the rudder.

(3) The maximum moment of the tail surface forces about the centre of buoyancy was 37,200 lb. ft.

(4) The investigation of the envelope pressures, while showing the general distribution of pressure satisfactorily, is practically useless in the determination of total aerodynamic forces on the airship.

(5) It is concluded that the pressures set up by a bump are larger than those obtained in manœuvring.

Report 245, Meteorological Conditions along Airways. By W. R. Gregg. 16 pages, illustrations, quarto. Washington, Government Printing Office, 1926. Price, ten cents.

This report was prepared at the suggestion of and for publication by the Committee and is an attempt to show the kind of meteorological information that is needed, and is in part available, for the purpose of determining operating conditions along airways. In general, the same factors affect these operating conditions along *all* airways though in varying degree, depending upon their topographic, geographic and other characteristics; but in order to bring out as clearly as possible the nature of the data available, a specific example is taken, that of the Chicago-Fort Worth Airway on which *regular flying begins this year*.

THE UPPERMOST REGIONS OF THE EARTH'S ATMOSPHERE, being the Halley Lecture delivered on May 5, 1926. By G. M. B. Dobson, Lecturer in Meteorology in the University of Oxford. 22 pages, 8vo. New York, Oxford University Press, American Branch, 1926. Price, $.85.

The problem of the upper atmosphere has become of considerable interest of recent years in view of the discovery of the inactive gases which are present in minute amounts in the air at lower levels, but may be more abundant at higher levels. There must be, however, a good deal of uncertainty about the exact conditions at great altitudes. The present essay is concerned principally with the phenomena that take place in the upper regions and not so much with the composition, although a statement is given of the relative amounts of nitrogen, oxygen, argon, helium, neon and hydrogen at heights ranging from sea-level to 300 kilometres (about 200 miles). An illustration shows the heights at which some of the more striking phenomena occur. The aurora borealis is fixed at about 70 miles, the layer reflecting radio waves at night at about fifty miles, the clouds luminous at night are somewhat below this and ozone is formed at about forty miles. The layer reflecting radio waves by day is fixed much lower. Thunder clouds and the common cirrus are, as is well known, quite near the earth, especially the former. A number of interesting and striking photographs are included in the pamphlet.

PUBLICATIONS RECEIVED.

Organic Chemistry, by William Albert Noyes, Director of the Chemical Laboratory of the University of Illinois. 677 pages, illustrations, 8vo. New York, Henry Holt and Company, 1926. Price, $3.50.

Canada, Department of Mines, Mines Branch. Final report of the Peat Committee appointed jointly by the Governments of the Dominion of Canada and the Province of Ontario. Peat, Its Manufacture and Uses, by B. F. Haanel. 298 pages, illustrations, plates, 8vo. Ottawa, King's Printer, 1926. Molybde-

num: Metallurgy and Uses and the Occurrence, Mining and Concentration of Its Ores, by V. L. Eardley-Wilmot. 292 pages, illustrations, plates, maps, 8vo. Ottawa, King's Printer, 1925.

Faraday Society. Photochemical Reactions in Liquids and Gases. A general discussion held October, 1925. 658 pages, illustrations, 8vo. London, Faraday Society, 1926. Price, fifteen shillings six pence.

Optical Society. Subject Index of the Transactions, Vols. I–XXV, by A. F. C. Pollard, Honorary Secretary of the Society. 89 pages, 8vo. Cambridge, University Press, 1926.

The Decimal Bibliographical Classification of the Institut International de Bibliographie, partly translated for the formation and use of a universal bibliographical repertory concerning optics, light and cognate subjects, by A. F. C. Pollard, Honorary Secretary of the Optical Society of London. 109 pages, illustrations, 8vo. Cambridge, University Press, 1926.

The Uppermost Regions of the Earth's Atmosphere, being the Halley lecture delivered on May 5, 1926, by G. M. B. Dobson. 22 pages, plates, 16mo. Oxford, Clarendon Press, 1926. Price, 85 cents.

Nueva Solucion del Problema de Lord Kelvin sobre Ecuaciones de Coeficientes Reales, por José Isaac Corral. 89 pages, 8vo. Madrid, Imprenta Clásica Española, 1926.

National Advisory Committee for Aeronautics: Technical Notes, No. 239, Steam Power-plants in Aircraft, by E. E. Wilson. 30 pages, illustrations, plates, quarto. No. 240, The N. A. C. A. Cyh Airfoil Section, by George J. Higgins. 4 pages, illustrations, 8vo. No. 241, Tests of Several Bearing Materials Lubricated by Gasoline, by W. F. Joachim and Harold W. Case. 19 pages, plates, 8vo. Washington, Committee, 1926.

U. S. Bureau of Standards: Scientific Papers, No. 525, A Unicontrol High-frequency Radio Direction Finder, by F. W. Dunmore. 11 pages, illustrations, 8vo. Washington, Government Printing Office, 1926. Price, five cents.

Solid Helium.—A note in *Nature* (1926, **118**, 58) gives the information that Prof. William H. Keesom, successor to H. Kamerlingh Onnes, University of Leiden, has succeeded in solidifying helium under a pressure of 150 atmospheres at its boiling-point and under a pressure of 28 atmospheres at a temperature of 1.5° K. Solid helium is transparent. H. L.

Occurrence of Acetone in Milk.—The work of F. F. SHERWOOD and B. W. HAMMER (*Agric. Exp. Station Iowa State College of Agric. and Mechanic Arts Research Bull.*, No. 85, 1925, pp. 173–179) shows that acetone is usually, though not invariably, present in the raw fresh milk of individual cows. It is regularly present in the mixed milk of a dairy herd. When pure cultures of starters are introduced into milk, the growth of these microörganisms does not significantly influence the acetone content of the milk. The iodoform test and the reaction with salicylic aldehyde in the presence of potassium hydroxide were used for the detection and determination of acetone in the distillate from the milk. J. S. H.

CURRENT TOPICS.

The Industrial Uses of X-rays—The Present Position. G. W. C. KAYE. (*Brit. Jour. of Radiol.*, April, 1926.)—The unequal absorption of X-rays by different kinds of matter and their diffraction have found application in the industries and the arts. In industrial radiography the scattering of the rays has to be reckoned with. When a beam of the rays traverses a substance, part of it emerges unchanged and undeviated. This casts the shadow on the photographic plate. A second part is absorbed and produces characteristic X-rays and electrons. The remainder of the original beam is scattered or dispersed. This is accompanied by a small change in wave-length, but often by a considerable change in direction. Thus it comes that the energy reaching a point well within a body may be chiefly that arriving by indirect routes due to scattering. Scattering causes a kind of fogging of the image that impairs definition with thin bodies and with thick ones renders good results impossible.

Examination by X-rays is especially valuable because it does not ordinarily injure what is examined. This was, however, scarcely the truth in an instance quoted in the discussion at the close of the paper, when, during the war, the French Customs authorities X-rayed a quantity of X-ray plates in an endeavor to discover what was in the case containing them. Furthermore the existence of a way of detecting hidden flaws and poor work has a moral influence upon workmen.

The invention of the Coolidge tube opened an era in the technical applications of X-rays. With a fluorescent screen not as small a difference of absorption can be detected as with a photographic plate. When large numbers of specimens are to be examined the screen is quicker and cheaper. Speakers from the Research Department, Woolwich, later stated the cost of testing by X-rays to amount to about one farthing per square inch of surface to which must be added from 10 to 20 per cent. for the labor used. A case was cited where it cost 10 shillings to examine a part of a war machine on which 60 pounds have been spent in machining it.

Mr. Kaye discussed the difficulties arising from the shapes of the pieces under examination and some remedial devices were presented. At present the maximum thickness of steel for which X-rays can be used is about 2 inches when photography is employed and one-quarter as much for the fluorescent screen. Greater penetration can be got by applying higher voltages to the tube producing the X-rays, but it is not easy to construct tubes that will stand more than 200,000 volts. Steel welds of the thickness of an inch have been successfully photographed. Blisters, blow-holes and lack of bonding can thus be detected but not the burning of adjacent metal.

The following is a partial list of applications of X-ray examination: To detect bits of metal in insulating fibre, to establish the centrality of the metal in electric cables, to find whether steel balls are sound, to tell whether the stems of thermometers are made of soda-glass or of lead-glass, the centrality of cores in golf balls, the fit of a shoe on the foot, to detect defects in artificial teeth, to estimate the amount of ash in coal, to count the turns of wire in a coil covered with insulation, to get the internal diameter of metal tubing, to examine the internal construction and assembling of explosive devices in the Woolwich Arsenal, the examination of mummies for diseases, the separation of genuine paintings and furniture from forgeries. An attempt to X-ray the mummy of Tutankhamen was frustrated by the large quantity of gold about the body. The applications hitherto enumerated depend on the different absorption of the rays by the material penetrated.

Laue found that the regularly spaced planes of atoms in crystals diffract X-rays so that their wave-lengths can be determined. Thus X-ray spectroscopy came about with its methods of photographing both absorption and emission spectra. Conversely from data relating to X-rays the dimensions of crystals can be measured and the arrangement of the constituent atoms determined. The effect on the orientation of crystals produced by annealing, tempering, rolling and working, as well as what occurs in the deformation of metals has been examined by X-ray diffraction. It has further been made clear that such supposedly amorphous substances as rubber, cellulose, soap, leather, bamboo and talc really have crystalline structure. Dr. E. A. Owen in the discussion stated that in factories materials in mixtures are identified by their X-ray diffraction. He reported on the effect of rolling a sheet of aluminum 10 mm. thick down to a thickness of .1 mm. In the original sheet the crystals were of appreciable size and arranged in no particular manner. In the final thin sheet all the crystals were located in the same way.

G. F. S.

New Elements and Atomic Numbers.—As is generally known to chemists, Moseley in 1913 made the important and valuable discovery of the relations of the atomic numbers from which has been obtained a guide to the suggestion of new elements superior even to the familiar periodic system. By his death in the British service in the Dardanelles in 1915 science lost a very valuable worker. The atomic number is determined by the number of electrons in the atom round the nucleus or the number of free electrons in the neutral atom or the number of free positive charges in the nucleus. Moseley thus corrected those instances in the periodic table in which it was known that the properties of certain pairs of elements demanded that their positions should be interchanged, an arrangement which could not be reconciled with their atomic weight. This summary of

Moseley's work is given by N. M. Bligh, F.C.S., in *Science Progress* (1926, **20**, 109).

At the time Moseley published his work several numbers were unfilled: 43 and 75, analogues of manganese; 61, a rare earth element; 85, a halogen; 87, an alkali metal; and 91, just below uranium. Whether there are any elements above uranium, that is, above 92, cannot be positively stated. Some chemists incline to a limit at this point. Gaps have been filled since Moseley's death. In June, 1925, 43 and 75 were discovered by Noddack and Tacke in Berlin, termed, respectively, masurium and rhenium. These are names of territories affected by the Versailles treaty, and the affixing of their names to the new elements seems to have more than a sentimental significance. In March, 1926, B. S. Hopkins, of the University of Illinois, announced the discovery of an element with the atomic number 61, which has been called illinium. It lies in the group of rare earth elements and completes the group. According to Bligh's paper interesting opportunities for discovery exist in connection with the missing 85, a halogen, and 87, affiliated with potassium.

In this connection it may be worthwhile recalling that shortly after the development of the spectroscope as an instrument of research, Bunsen and Kirchhoff, of Heidelberg, discovered cæsium and rubidium by means of the instrument. Chemists were in those days somewhat astonished at the fact that to obtain a little over a hundred grains of the mixed chlorides of these two elements about 20 tons of water of one of the German springs were evaporated. The yield of radium from its richest ores is far less than this.

H. L.

New Types of Cotton and Rubber.—O. F. COOK, J. W. HUBBARD, and F. C. BAKER, members of the Bureau of Plant Industry, U. S. Department of Agriculture, who have returned recently from a three months' exploration trip in the West Indies and South America, report cotton plants having characters that may be of value in the United States. One type has bracts open or turned back from the buds and young bolls affording little protection for boll weevils or other pests and diseases. The cotton can be picked with less "trash" or broken bract material and grades would be improved.

Rubber experiments conducted by the department in Haiti and in the Canal Zone were visited, a short expedition was also made to the west coast of South America, and into Columbia and Ecuador as far south as Guayaquil. Here they traced the Central American (*Castilla*) rubber tree. The species growing in South America are different from those of Central America, however, and a different method of tapping is used. In South America the trees are felled and the trunks ringed at intervals of a foot or more to get the rubber latex.

More rubber can be obtained from *Castilla* than from *Hevea*,

with the same amount of labor, but as yet no system of regular production from *Castilla* has been devised.

Experimental plantings of the *Hevea* or Para rubber tree are being made by the department at many places in the Canal Zone, the Republic of Panama, and Haiti, in order to determine the range of conditions under which the trees will grow and produce rubber. Results of tapping experiments conducted on twenty-year-old trees now growing near the north coast of Haiti indicate that it is not impossible to produce rubber from this tree in suitable locations in the West Indies, Central America, and Mexico. Seed of the *Hevea* brought to the Canal Zone from Haiti has produced healthy seedlings which are now being transplanted. H. L.

The Applications of Seismology. E. ROTHÉ. (*Revue Scientifique*, June 12, 1926.)—The seismograph is of special value because it is the only instrument by which we can sound the interior of the earth, discover its anomalies and gain an opinion about the nature of its deep-seated layers. By this instrument alone do we get information concerning the speed of propagation of elastic waves through the earth or along its crust. In addition to these somewhat recondite aspects seismology is applied to matters of technical importance. There are so many of these that Professor Rothé devoted his course last winter in the University of Strasbourg to their consideration.

As long ago as 1665 one of the architects of the cathedral of Strasbourg found small cracks in a pillar of the tower. No serious result followed. In 1903 and again in 1907 remedial measures were applied but more radical relief become necessary and quite recently a new foundation was laid beneath the pillar. "The daring of this operation is seen when it is stated that there was a time when the base of the pillar of the tower was in sight supported above the heads of those engaged in the work." To keep watch on any yielding or slanting, horizontal pendulums were installed and the light reflected from their mirrors was carefully watched until the work came to a successful end.

The Institute of Terrestrial Physics at Strasbourg has recently set in operation a large seismograph with a weight of 19 tons. Motions of the earth are magnified 2000-fold and recorded mechanically. Located as it is in the gardens of the University this instrument is away from electric cars and automobiles, and a kindly ordinance of the city excludes heavy vehicles from the adjacent streets. Yet the industrial life of the town is near enough to write its record on the graph. There are mills, rolling mills, wood-working plants, etc., with a total horse-power of about 30,000 within 2 km. of the instrument. Curves are printed showing the Sunday and week-day vibrations. From 6 A.M. Sunday, only the electric plant is running. There is a marked change in the record during Saturday night, for many large establishments run to 10 P.M.; then at 6 A.M. the rolling mills stop work. During Sunday only small vibrations appear on the

sheet. At 3 A.M. Monday the firemen arrive at the various plants and start the boilers and this is at once registered by slight movements of the earth. Other operations follow and within two or three minutes of 6 A.M. the industrial life of the city has recorded its revival. Such observations as those made at Strasbourg show that industrial plants set up earth waves that may injure buildings nearby, especially if sympathetic vibration is produced by the coincidence of the period of the vibration with the natural period of the structure. In consequence of this there is a demand for portable seismographs and accelerometers. Japan has studied its earthquakes to such purpose that its buildings stand shock better than formerly. G. F. S.

AN EDITORIAL in *The Electrician* discusses the bearing of the development of hydro-electric power upon the coal mining industry of Great Britain. A conservative estimate made by the United States Geological Survey places the total possible water-power of the earth, apart from its coasts, at 453,000,000 H.P. No less than 41 per cent. of this lies in Africa, where the basin of the Congo offers the largest source of energy. Between the close of 1921 and the present time the world's output of energy from water-power has increased from 23,000,000 to 35,000,000 H.P. In the British Empire, Canada seems to be accomplishing most in this direction. The year 1925 saw 600,000 H.P. put into service, including the eight turbines of 50,000 H.P. at Isle Maligne. In the same year in the United States of America two and a half times as many horse-power were set in operation as in her northern neighbor and many additional plants are projected. Brazil with its total possibilities of 25,000,000 H.P. has up to the present developed only a few per cent. of this amount.

In Europe, Switzerland, even as long ago as 1894, held a leading place in hydro-electric plants. The recent opening of the installation on Barberine River, Canton Valais, is claimed to render the entire country independent of foreign coal. The rate of increase in Europe has exceeded that in the United States and Canada, for from 1921 to 1923 the hydro-electric output rose from 8,877,000 H.P. to 12,300,000 H.P., a gain of more than 40 per cent.

No matter what readjustments of wages, working hours or of more efficient machinery be made, the competition of hydro-electric power must be confronted by the mining industry. Since countries on the Continent are employing more water-power, there seems no escape from the conclusion that they will require a smaller quantity of coal. France, for example, had in 1921 1,400,000 H.P. from her hydro-electric plants. Two years later the output had increased by 50 per cent. "Every possible attempt is being made by the latter country to render herself independent of foreign coal and liquid fuel and certainly to-day well over 2,500,000 H.P. is being obtained from water, so that we can regard the coal trade with this country as almost lost, while the same is beginning to apply to Italy." Since the amount of coal in the earth is a finite quantity, it will at some time

in the future be exhausted. Such a crisis as appears to confront the British mining industry is inevitable for all mining countries in the transition from coal to whatever shall replace it, whether solar energy or energy from other sources. G. F. S.

Fraunhofer and His Spectroscopic Discoveries. ERNST LAU. (*Zeit. f. Tech. Phys.*, **7**, No. 6.)—Joseph Fraunhofer was born March 6, 1787, and died June 7, 1826. In observing the centenary of his death more than one German periodical has published a memorial number. Among the articles concerning him in the anniversary number of this Zeitschrift is one telling how he came to observe the dark lines in the solar spectrum that bear his name. He was engaged on the problem of preparing achromatic objectives for astronomical telescopes and for this he needed to know the indices of refraction for different colors of light possessed by each kind of glass. No accurate methods were at his disposal. He changed the angles of flint-glass and of crown-glass prisms, hoping to come upon the right combination, but he was without success. He then resorted to six lamps by means of which he got six lights of different colors, of which he determined the indices of refraction. His account of what followed is from his paper, "Determination of the Refractive and Dispersive Power for Different Colors of Light of Various Kinds of Glass in Relation to Perfecting Achromatic Telescopes." "To get even more accurately the coefficients of the refractive relations of the different colored rays, in part also to discover whether the effect of the refracting medium on sunlight be the same as on artificial light, I took the trouble to make an apparatus that was the same for sunlight as the above-mentioned one was for lamplight. This, however, soon became superfluous.

"In a darkened room through a narrow opening in the shutter I let the sunlight fall on a prism of flint-glass mounted on the theodolite above described. I desired to examine whether in the colored band formed by sunlight there was to be seen a bright stripe similar to that appearing in the band from lamplight (by which the D lines are meant) and I found instead of it with the telescope almost numberless strong and weak vertical lines, which were, however, darker than the rest of the band of color. Some seemed to be totally black." He used a 60° prism in the position of minimum deviation.

Fraunhofer convinced himself by experiment that the relation of the lines to one another was independent of the slit, the angle of the prism and the kind of glass in the prism, and that they "lie in the nature of sunlight." He saw both D lines and applied the capitals from A to J to prominent lines.

In 1802, about fifteen years earlier, Wollaston had described dark lines in the spectrum of sunlight, but he did not recognize that they were due to the sunlight itself. Fraunhofer had no knowledge of this previous discovery. The fundamental and thorough character of his work justify the name "Fraunhofer's lines." He subsequently

discovered in the spectrum of light from Venus and the moon lines already familiar to him in sunlight. He further noted that the spectrum of Sirius was of a different kind. He saw that the bright yellow lines obtained from flames came in the same place as the D lines in the solar spectrum, but the connection between an element and its lines remained unknown to him. G. F. S.

The Féry Primary and Secondary Batteries. (*J. Scient. Instr.*, June, 1926.)—At the fifty-eighth annual exhibition of the French Physical Society, Féry, who is known for his work in radiation pyrometry, appeared in a new rôle as a designer of electric cells. Though primary cells are relatively less important than a generation ago, still their value is by no means negligible, and Professor Féry has done a good work in improving the Leclanché cell. This has the drawback that its zinc is eaten away at the surface of the liquid and that its porous pot becomes clogged with insoluble crystals. Professor Féry eliminates the first of these by removing the zinc from the surface and placing it as a flat plate in the bottom of the cell, and the second by doing away with the pot and the contained manganese dioxide. The carbon in the form of a long cylinder extends downward through the liquid to a level a short distance above the zinc. The liquid is merely an aqueous solution of sal ammoniac. While the current is flowing, the zinc combines according to this reaction, $Zn + 2NH_4Cl + 2H_2O = ZnCl_2 + 2NH_4OH + H_2$. The rather heavy $ZnCl_2$ solution stays at the bottom; the lighter ammonium hydrate rises and the liberated hydrogen also rises and either attaches itself to the carbon or escapes at the top. It is disposed of in the latter manner when the currents are small. For large currents, however, it reacts with the zinc chloride to form zinc hydrate, which, fortunately, is readily soluble both in the zinc chloride solution and in the ammonium hydrate. Thus it comes about that only at the meeting place of the zinc chloride with the sal ammoniac solution, not far from the middle of the carbon cylinder, are insoluble crystals of double oxychloride of zinc deposited, and the working of the cell is little affected. The presence of hydrogen on the carbon would cause the usual polarization effects, but in the oxygen dissolved in the upper part of the battery liquid unites with the hydrogen. No solid is deposited on the zinc plate and it is free from local action, so that, being dissolved only during the flow of the current, it lasts well. "A battery of 61 cells having an initial E.M.F. of 78 volts was put in the telegraphic service at Epernay on March 31, 1920, and after three hours had an E.M.F. of 72 volts, which had fallen to 61 volts by March 16, 1922, when a cracked cell was remounted, and the battery was still in satisfactory service up to October 15, 1922, or after two years and seven months of use. The internal resistance of the battery was about 15 ohms or .25 ohm per cell three months after commencement, rising to about one ohm per cell after nearly two years, and the zinc plates dissolved quite uniformly." Professor

Féry has developed a new theory of the reactions occurring in lead accumulators and presented it to the Academy of Sciences. In his storage cell he puts the negative plate flat at the bottom in a solution that does not change and away from the air. On this plate is a layer of porcelain granules soaked in the acid solution upon which rests the positive plate. Double sulphation is avoided. Such a cell can be discharged below the usual limit and can be left discharged for a long time without detriment. Since these cells are of rather large resistance they are suited for only certain purposes, being especially useful where employment is intermittent and oversight a minimum.

G. F. S.

On Lightning. G. C. SIMPSON. (*Proc. Roy. Soc.*, A757.)—A discharge of lightning follows one of these three types of paths: (*a*) Between the ground and a part of the atmosphere having a volume charge, commonly a cloud; (*b*) between two parts of the atmosphere having volume charges of opposite signs, and (*c*) between a part of the atmosphere having a volume charge and a part without a volume charge.

Let us consider a spherical cloud with a positive charge throughout its volume. Lines of force pass from it to the negatively charged earth beneath. The greatest electrical intensity is at the lowest point of the cloud and it is there that the air will break down first with the production of ions. A sort of conducting channel will extend downward from the cloud. It might seem that subsequent developments should be the same no matter whether the cloud has a positive or a negative charge, but this is far from being true. In the conducting channel below a positively charged cloud, both positive ions and negative electrons have formed. The negative electrons have been attracted upward to the positive cloud and, since they move with far more freedom than the positive ions, they have moved rapidly upward and have neutralized a part of the positive charge of the cloud. Their departure from the region of ionization leaves only the positive ions there, so that this region with its positive volume charge becomes virtually an extension of the positively charged cloud. The positive ions have too small a mobility to be driven far into the surrounding air by the repulsion of the similarly charged cloud. Therefore the region of ionization scarcely tends to widen. It does, however, extend further and further downward, for at its lower end the electric intensity is high, so that additional ionization is produced. This extension may proceed until the conducting channel reaches the ground, or it may go some distance and stop, because the upward flow of negative ions has neutralized the original positive charge of the cloud to such an extent that the intensity has fallen below that necessary for ionization. Irregularities at the end of the channel manifest themselves as places of maximum or minimum intensity. The discharge will follow the former and avoid the latter, so that it is not difficult to see why a discharge bifurcates.

Suppose, on the other hand, that the cloud is negative. Ionization occurs beneath it. The positive ions are so sluggish that they scarcely move before the mobile negative ions are attracted to them and neutralize them. The negative ions, however, are repelled outward and thus the conducting channel in this case spreads out, thus losing its ability to cause further ionization, whereas with a positive cloud the channel remains limited and thus can propagate itself downward. Owing, therefore, to the difference between the mobility of positive ions and negative electrons, a discharge will travel away from a positive cloud but will not travel from a negative cloud. This conclusion was attested by photographs of the discharge between two circular electrodes oppositely charged by a Wimshurst machine, between a positively charged ball and a negative plate and between a negatively charged ball and a positive plate.

The author assembled 442 photographs of lightning. He says: "I was considerably surprised to find that while 242 of these photographs showed branched discharges with the branches directed away from the cloud, only three, two of which are very doubtful, had the branches directed toward the cloud. . . . So far as the evidence of these photographs goes there can be little doubt that a large preponderance of the low clouds with which visible discharges are associated are positively charged."

Discharges between cloud and earth have been considered, but just the same reasoning applies to a discharge between two clouds. The author saw in India discharges leave the lower part of a cumulus cloud and travel leisurely outward in a horizontal direction. He presents this explanation. The positive discharge starts from the cloud, ionizes the air and sends the negative ions along the conducting channel to the cloud. The rate of growth of the channel depends on the rate at which the cloud can absorb these ions. If it absorbs them quickly the channel grows rapidly. If it is too slow in absorption, the channel will cease to lengthen. For some intermediate rate of absorption the channel will extend itself slowly as it was seen to do in India. It is interesting that the author is the man who has furnished so satisfactory a theory of the origin of the electricity concerned in lightning. G. F. S.

Heike Kamerlingh Onnes, 1853–1926. G. L. DE HAAS-LORENTZ. (*Naturwissenschaften*, May 14, 1926.)—In relation to its population Holland has given to the world an extraordinarily large number of distinguished men, and this continues to be true in the twentieth century. From 1915 to 1926 twenty-four awards of the Franklin medal have been made. Of these citizens of Holland have received three and citizens of the United States four times as many. Holland has an area about the same as that of Maryland and a population considerably less than that of Pennsylvania. It may be said that The Franklin Institute has given one Franklin Medal to each group of 2,280,000 people in Holland and of 9,000,000 in

the United States of America. The three Dutch recipients of the Medal are Pieter Zeeman, Hendrick A. Lorentz and Heike Kamerlingh Onnes.

After his student days in his native land Kamerlingh Onnes studied with Bunsen and Kirchhoff in Germany in 1871 and 1872. At home he had won medals for good work at the universities of Groningen and Utrecht and a similar distinction came to him from Kirchhoff. After holding a subordinate position for some years in the Polytechnic School at Delft in 1882 he became professor of experimental physics at the University of Leiden, where he passed the remainder of his life. Five years earlier H. A. Lorentz had begun his tenure of the chair of theoretical physics in the same institution. In his inaugural address Kamerlingh Onnes emphasized the importance of measurement, saying: "I should like to put as a motto on every physical laboratory 'Through Measurement to Knowledge.'" He devoted himself to a study of van der Waals' equation of continuity, then a new thing, and through it came to the main physical interest of his long life of investigation, the production of low temperatures and the study of physical properties at low temperatures. He went on from the liquefaction of oxygen to that of hydrogen and finally of helium in 1908. This last result came to crown years of study of the characteristics of gaseous helium and of the laws of corresponding states. Now, after his pioneer work, MacLennan in Toronto and Meissner in Berlin produce this rare liquid. Much work was done in his laboratory on the isotherms of gases and of gaseous mixtures, and on other relations applying to them. An interesting result was found for a mixture of hydrogen and carbon dioxide. Both these gases depart from Boyle's law, but they depart in opposite directions. It was thus possible to form a mixture of the two that conformed exactly to Boyle's law. This mixture contained 80 per cent. hydrogen. Capillarity and viscosity were investigated, but the most important result was obtained in the field of electric conductivity. If a wire of lead be cooled lower and lower its resistance grows less, then at some temperature the resistance suddenly diminishes but remains measurable. As the temperature still falls a state is reached when the wire no longer has a resistance that can be measured.

The cryogenic laboratory at Leiden became a Mecca for physicists with low-temperature problems to solve. Vegard, for example, went there from Norway to endeavor to find in solid nitrogen the origin of the green auroral line. It must not be thought, however, that other types of investigation were lacking in the Leiden laboratory. The Kerr phenomenon, the Hall effect, were there studied, and it was there that Zeeman did the preliminary work that led to his discovery of the manifolding of spectral lines by the influence of a magnetic field. As the chief distinctions that came to him from

other countries are mentioned the Nobel Prize, the Baumgarten Prize, the Rumford Medal and the Franklin Medal. In the early part of the present year his long and useful career came to end.

G. F. S.

Photophoresis. H. S. PATTERSON and R. WHYTLAW GRAY. (*Proc. Leeds Phil. and Lit. Soc.*, **1**, pt. 2, 1926.)—In 1918 Ehrenhaft introduced this term to denote the motion of minute particles of various substances in gases under the influence of a beam of intense light. After the pressure of light had been measured the deflection of small particles by a beam of light was demonstrated at a meeting of the A.A.A.S. and, doubtless, elsewhere also. The striking feature of Ehrenhaft's observations lay in his seeing that some particles moved with the light flux (light positive particles) while others travelled toward the source of the light (light negative particles). According to him particles of gold, silver, mercury, cadmium, sodium and magnesium are light positive but particles of sulphur, selenium, iodine and cigarette smoke are negative. Droplets of water do not move in either direction in the beam. Much labor has been expended in endeavoring to account for this effect. Ehrenhaft attributed to the pressure of light the motion away from the source and to some unknown interaction between radiation and matter the motion toward the source. He further showed that the phenomenon was not due to an electric charge on the particle or to convection currents in the gas. The force acting was not dependent on the pressure of the gas down to 16 mm. mercury. Selenium initially light negative was found to develop light positive particles after a time. This was ascribed to a change of allotropic form. Light negative motion has been attributed to radiometer action and the theory has been elaborated only to have its weakness and insufficiency pointed out.

In the present lack of a satisfying explanation it seemed desirable to repeat the experiments. A beam of light from an arc was focussed in the centre of a litre flask containing the particles to be observed. They could be seen to move either with the naked eye or with a low-power microscope. The gas pressure was reduced to about 1 cm. in order to get velocities near 1 cm./sec. It was usually satisfactory to put the finely divided solid in the flask and then to shake it. A large number of substances were tried and with nearly all definite effects were discovered. In the case of the following the effect was either quite wanting or very small, calcium sulphate, calcium fluoride, antimony trioxide, smalt and magnesium oxide as well as oil droplets and water particles. Especially large effects were found with lamp-black, graphite powder, iron filings, potash alum, brilliant green and methylene blue. With most substances both light negative and light positive particles were seen. In no instance was negative motion observed without positive motion in the same substance, and it was always true that more particles travelled with the

light than against it. The relation of the number of light positive to that of light negative particles varies greatly from one substance to another. Once in a while a particle reversed its motion and retraced its path.

A second beam with its axis at right angles to the first was focussed on a point in the flask situated in the first beam after it had passed through its focus. Particles then came along the first beam and made a 90° turn and moved along the second. The authors have considerably extended our knowledge of what takes place in photophoresis, but they offer no theory to account for it. They do however, promise more experiments. G. F. S.

The Hydro-electric Exploitation of the Aspe Valley. (*Rev. Gén. l'Électricité*, July 3, 1926.)—The head of this valley is about 50 km. southwest of Lourdes and, perhaps, 70 km. to the southeast of Roncesvalles, where Roland and other paladins of Charlemagne were slain in a rearguard action in 778. A company has a concession for the water rights for a distance of 50 km. along the stream. There is a total difference of level of 1490 m. of which 1345, or 90 per cent., will be utilized. Naturally it is desired to get the maximum output with the least outlay. The application of this principle has led to the decision to have seven plants. Of these four will be dependent chiefly on the natural flow of the stream with little assistance from dams. Two others will have reservoirs to hold the water that runs in the night so that it may be available for running the dynamos in daytime. The remaining installation with a large storage reservoir may be increased by another with the highest head of water utilized in France. The first of the plants to be erected was that at Esquit, situated near the middle of the concession, so that power there generated might be used in the construction of the remaining plants. The fall at Esquit is 42 m. and the discharge 13.5 $m.^3$ per sec. Turbines with horizontal axes drive three three-phase alternators, 50 cycles, 1700 KV-A. The voltage is 6000, which is stepped up to 66,000 for transmission. The completed valley installation is expected to give 300,000,000 kilowatt-hours per annum with a maximum output of 50,000 kilowatts. There is a ready demand for the power generated for use in industrial, mining and metallurgical plants. Power is transmitted to Bordeaux and Agen in the north and as far east as Toulouse. G. F. S.

Cementation of Steels with Silicon. L. GUILLET. (*Comptes Rendus*, June 28, 1926.)—In the course of a general study of cementation the penetration of silicon into steel was studied. Fry had found that, even after 110 hours, silicon had made its way into soft iron to a distance of only .6 mm., and that the surface content in Si was not greater than 2.5 per cent., the temperature having been

1150° C. Strange to say the percentage was larger when the applied temperature was 200° lower. The author set about obtaining a much higher content of silicon, having in mind the considerable industrial importance of such combinations of iron and silicon.

He used ferro-silicon with 75 per cent. to 80 per cent. of the latter. This was powdered and sometimes mixed with ammonium chloride and silica. The circular rod of steel to be acted on was 1 cm. in diameter and contained .2 per cent. carbon. The whole was buried in charcoal. When NH_4Cl was added to the ferro-silicon six and three-quarters hours' exposure to the temperature of 1200° C. resulted in the silicon penetrating to the centre of the rod. In briefer experiments as high as 15.5 per cent. silicon was found present. Cementation proceeded more rapidly in the presence of NH_4Cl. Silica seems rather to retard the process. In all cases of cementation the resulting surface layer is brittle. The author hopes to change this objectionable quality by reheating. G. F. S.

On the True Significance of Fizeau-Zeeman's Experiments. CHARLES L. R. E. MENGES. (*Phil. Mag.*, May, 1926.)—In 1851 Fizeau compared by an interference method the velocity of light in two parallel tubes filled with flowing water, the direction in one tube being opposite that in the other. Einstein has claimed that, though his theory of relativity took its rise from the Michelson-Morley experiment, the Fizeau effect in reality forms the crucial test of it. The author states that he has been able to furnish a mathematical explanation of the results obtained without the use of doubtful hypotheses and that his explanation leads to a radically different interpretation of the data furnished by experiment. He makes the claim that, in view of the new light he has cast upon the experiment "Einstein's theory cannot be maintained."

(By an unfortunate oversight Menges, JOURNAL OF THE FRANKLIN INSTITUTE, June, 1926, p. 822, was quoted as saying "Zeeman's result [in repeating the Fizeau experiment] is the decisive proof of Einstein's theory." For "proof" the word "disproof" should be read.) G. F. S.

A New Process for Making Transparent, Stretched, Metallic Membranes. K. LAUCH and W. RUPPERT. (*Physik. Zeit.*, July 1, 1926.)—K. Mueller in the Reichsanstalt devised a method of preparing such thin metallic sheets. He deposited by electrolysis upon copper foil a thin layer of the desired metal and covered this by further electrolysis with a film of copper. The copper on both sides of the metallic layer was then eaten away by acid. Thus metallic membranes as thin as .00001 mm. were made. Their handling after they had been freed from the copper required great skill.

The process described in this paper emanates from the physical laboratory of the University of Leipzig, where Prof. Otto Wiener

still works. He it was who about 1888 succeeded in getting a photographic record of standing light waves. The new process has the advantages that it requires only two or three hours, that it produces thinner films and that it is applicable to all metals, acids not being used to dissolve the supporting frame. The central part of a highly polished face of a crystal of rock salt is covered with a round glass disc. The parts of the face not thus protected are then exposed to cathode sputtering by which a thick, opaque layer of metal is deposited. The glass disc is next withdrawn and by sputtering a layer as thick as is desired is deposited on the circle. After removal from the vacuum vessel where the deposition took place the crystal is slowly dissolved in water, leaving the thin central film supported all around by the thicker rim of metal first deposited. Thin metallic films thus made are surprisingly strong and elastic. One of silver .00003 mm. thick when blown upon was set in vibration and emitted audible air waves without being broken. A similar film 6 mm. in diameter withstood a pressure of 8 mm. of mercury. By this process metallic membranes, highly polished and free from holes, were produced that were only .000005 mm. thick. The thickness was determined by comparing the intensity of the transmitted light with that penetrating a wedge of metal of known dimensions. When the metallic membrane does not need a high polish it can be deposited on the surface of a solid made by compressing salt instead of on a natural crystal.

G. F. S.

Improved Gutzeit Test for Arsenic.—GEORGE KEMMERER and HELMUTH H. SCHRENK, of the University of Wisconsin (*Ind. and Eng. Chem.*, 1926, **18**, 707), find that the presence of more than traces of moisture produces uneven colors in this test for arsenic. To overcome this difficulty they recommend that the filter paper be dried for one hour at a temperature of 105° C., then be stored in a desiccator over calcium chloride. Strips of this dry paper are sensitized by saturation with a 1.5 per cent. solution of mercuric bromide in 95 per cent. ethyl alcohol, draining, and drying for ten minutes in a large desiccator; they are then used. The sensitized strips should never be kept for more than two hours before use.

J. S. H.

Effect of Moisture on the Loss of Sugar from Sugar Beets in Storage.—This problem has been studied by DEAN A. PACK, of the Bureau of Plant Industry, U. S. Department of Agriculture (*Jour. Agric. Research*, 1926, **32**, 1143–1152). He finds that dry storage accelerates and moist storage retards the loss of sugar from sugar beets during storage. The minimum loss of sugar occurs when the moisture of the environment is in equilibrium with the water content of the beet tissues. The beets should be kept alive in storage, be properly aërated, and be kept in a dormant state by storage at a low temperature, *e.g.*, 1.7° C.

J. S. H.

Arsenic in Sprayed Apples.—Cases of arsenical poisoning in England have been ascribed to the eating of imported apples. FRANK T. SHUTT, the Dominion Chemist (*Analyst*, 1926, **60**, 291–292) has analyzed the skin, calyx and stalk of 43 samples of apples which were grown in the Dominion of Canada, 8 samples in Nova Scotia, 8 in Quebec, 17 in Ontario, and 10 in British Columbia. These apples had been sprayed on the trees during the growing season with arsenical sprays, such as lead arsenate and calcium arsenate. Of the samples, approximately one-half were entirely free from arsenic, approximately one-sixth contained arsenic (arsenious oxide) in quantities less than 0.0001 grain per pound, and one-third contained arsenic in quantities from $\frac{1}{10,000}$ to $\frac{1}{190}$ grain per pound. The limit of arsenic suggested by the Royal Commission on Arsenical Poisoning in 1903 is 0.01 grain arsenic (arsenious oxide) per pound.

"The results of this enquiry furnish satisfactory evidence to the effect that a very large proportion of Canadian sprayed apples is entirely free from arsenic, and that in those cases in which the presence of arsenic has been detected the quantities are negligible."

J. S. H.

Federal Meat Inspection. (U. S. Department of Agriculture, Press Service, June 30, 1926.)—The full significance of the little purple stamp and other labels used for marking carcasses and products that have passed federal inspection is not appreciated by all consumers of meats. In order that people generally may better understand its meaning, the Department has just issued Miscellaneous Circular No. 63-M, entitled "The Inspection Stamp as a Guide to Wholesome Meat."

The Federal Government has no supervision over establishments which confine their business to the state where the animals are killed, such concerns being under state control. Cities can also supervise meats sold within their limits, just as they inspect local milk supplies. A large proportion of meat establishments do an interstate business, and about two-thirds of all animals slaughtered in the United States are federally inspected.

The present export trade in American meats, according to the circular, is possible largely because the federal inspection system enjoys the confidence of foreign governments.

Federal inspection of animals is made before and after slaughter. If the inspector sees an animal that looks sick or abnormal in any other way, he tags it with a metal label fastened to the ear, the tag reading either "U. S. Condemned" or "U. S. Suspect," depending on how serious the ailment is. If condemned, the animals so tagged must not be taken into the slaughter room. Animals whose condition

is merely doubtful are kept apart and slaughtered separately from other animals.

The circular, which is written in popular story form, gives numerous details relative to the federal meat inspection service.

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